Argonne National Laboratory

ENGINEERING DEVELOPMENT OF FLUID-BED FLUORIDE VOLATILITY PROCESSES

Part 16. A Safety Manual for the Engineering-scale Alpha Facility

by

B. J. Kullen, W. A. Murphy, E. L. Carls,
N. M. Levitz, G. J. Vogel, and R. V. Kinzler

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Chemical Engineering Division

April 1970

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ABSTRACT

This manual describes safety procedures and warning and protective devices used in the operation of a plutonium-processing facility. Hazards protected against are release of radioactive or other noxious materials, fires, criticality, failure of electric power, process abnormalities, and explosion hazards. Also considered are safe procedures for routine operations, such as processing operations, material transfer into and out of gloveboxes, and waste disposal.

1. INTRODUCTION

1.1 Purpose of the Manual

The processing of plutonium-containing materials by fluid-bed fluoride-volatility methods[1] introduces a number of unique safety problems, which demand careful planning of safety practices. One must consider not only safe procedures for handling plutonium, which is toxic and has associated radiation hazards (described in Appendix A), but the reactive nature of the process gases as well. Steindler[2] and Marchetti[3] have reviewed procedures developed by the nuclear industry for handling plutonium-containing materials in aqueous and solid (salt and metal) form on an engineering scale. Properties of process gases, such as fluorine, HF, the interhalogens (ClF_3, BrF_3, and BrF_5), oxygen and hydrogen, and general procedures for handling these gases are available in the Matheson Gas Data Book.[4] (See also Appendixes D and G.)

Familiarity with this information represents the first step in an education-training program for operating personnel. Manuals specific to given installations are also needed. This document sets forth the safety practices and describes the safety equipment used in the ANL Chemical Engineering Division engineering-scale alpha facility,[5] which was used in the development of fluoride-volatility processes. Although this manual is specific to a given facility, it presents an operating philosophy and, hopefully, will be useful to others performing similar work.

The alpha facility, general safety procedures, and emergency systems are described in the body of this manual. The appendixes contain reference information on plutonium and process reagents, details of safety equipment, and certain detailed safety procedures. Augmenting this material is the Argonne Radiation Safety Guide,[6] which describes general safety procedures. (Appendix C contains some excerpts from this guide.)

1.2 Hazards of Handling Plutonium

Safety in the alpha facility pertains largely to the biological and criticality hazards associated with plutonium (discussed in Appendix A). Plutonium is biologically hazardous as a toxic substance as well as a radiation emitter. Beta-gamma radiation (see Table V in Appendix A) and neutrons represent the external radiation-exposure hazard from plutonium and associated products. The beta-gamma radiation level in the facility is not expected to require shielding. Duration of working times for operators must be limited, however, when neutron levels are high. The human body has a particularly low tolerance for plutonium because it is an alpha emitter (see Section 1 of Appendix A). For these reasons, the goal of the safety program is <u>no</u> exposure to any form of plutonium.

Plutonium also presents a criticality hazard. Criticality control is based on limiting the quantity of plutonium and moderating material brought into the facility. Although approval was granted, after a criticality review of the facility, for the use of up to 2000 g of plutonium, the quantity of plutonium in the form of volatile hexafluoride in a single container was limited to 200 g. Since the 2000-g value is greater than the minimum critical mass of plutonium, strict regulations are followed regarding accountability and water control in the facility. (These regulations are listed in Section 3.2.4.)

All states of plutonium (solid, liquid, and gaseous), as well as natural and depleted uranium, are present in the facility. Recognizing the hazards pertaining to each form of plutonium is the first step toward successfully overcoming them.

1.3 Hazards Involved with Fluoride-volatility-process Chemicals

The engineering-scale alpha facility has been designed to handle the following volatile gaseous reagents: fluorine (F_2), hydrogen fluoride (HF), chlorine trifluoride (ClF_3), bromine trifluoride (BrF_3), and bromine pentafluoride (BrF_5).

In current process studies, fluorine is used to convert uranium oxides and plutonium oxide to gaseous hexafluorides to separate them from the bulk of the fission products. Prior to fluorination, hydrogen fluoride may be used along with oxygen to declad stainless steel fuel assemblies; HF is also a byproduct in the conversion of UF_6 and PuF_6 to their oxides in a later step. Chlorine trifluoride is used as a drying agent. Bromine trifluoride and bromine pentafluoride each may be used to selectively fluorinate uranium.

Aside from their radioactive properties, UF_6 and PuF_6 are strong fluorinating agents and therefore will be included in this discussion.

Hydrogen and oxygen are also both used in the facility. Hydrogen is used during the conversion of UF_6 and PuF_6 to their oxides and during a separate oxidation-reduction step. Oxygen is used to reduce the particle size of UO_2 in the hexafluoride-to-oxide conversion process as well as to disintegrate UO_2-PuO_2 pellets before fluorination (an oxidative pulverization process).

The important physical characteristics and pertinent handling procedures for all of these materials are listed in the appendixes. Hazards associated with these reagents are reviewed briefly below, and rules for handling them appear in Section 3.2.3.

1.3.1 Fluorine and the Volatile Fluorides

Fluorine and the volatile fluorides (F_2, HF, ClF_3, BrF_3, BrF_5, PuF_6, and UF_6) are very toxic and produce severe burns when they come in contact with the body or enter the lungs. Penetration of the skin by these materials (either anhydrous or aqueous solutions) is rapid and often requires calcium gluconate injections below the skin, which neutralizes the effect of the fluoride. (See Section 8 of Appendix E.) Dilute aqueous solutions of these fluorides, while capable of producing severe burns, may not be felt when they contact the skin. The odor associated with these materials is strong enough to make a person aware of toxic concentrations in the air. Assault masks and supplied-air respirators are effective for preventing inhalation of volatile fluorides; fluorine-resistant clothing must be worn when handling these materials. (Protective clothing is discussed in Section 3.1.2, and actions to be taken in the event of a chemically hazardous material being released are discussed in Section 4.4.2.)

Fluorine, ClF_3, BrF_3, BrF_5, UF_6, and PuF_6 are strong oxidizing agents. They will spontaneously ignite most organic materials at room temperature and may even react explosively with hydrocarbons. Teflon and metals, not properly fluorine-conditioned, will also be ignited by these materials at higher temperatures. Chlorine trifluoride has an additional hazard in that it reacts with water and other oxygen-containing substances to produce oxychlorides and oxyfluorides that are explosive.[7] Safety information for bromine trifluoride and bromine, along with medical treatment, is presented in Appendix E.

Concerning the engineering-scale alpha facility, the hazards in handling fluorine and interhalogens depend on whether the operation is inside or outside the glovebox. Operations outside the glovebox involve the normal hazards of personnel exposure and equipment damage. The use of these materials within the glovebox reduces the hazard of personnel exposure, but increases the hazards of fires and possible release of radioactive materials.

1.3.2 Hydrogen and Oxygen

Since hydrogen forms explosive mixtures with oxygen (or air) and fluorine, the primary concern in the facility is to prevent mixing of these gases.

2. DESCRIPTION OF THE ENGINEERING-SCALE ALPHA FACILITY

2.1 Facility Layout

This brief description of the facility is included only to provide background for the discussion of safety considerations.

The facility comprises two gloveboxes, an instrument panel area, and associated equipment. Construction details for a typical glovebox are given in Appendix I. The larger glovebox houses two fluid-bed process systems. The key units are a 3-in.-dia fluid-bed reactor (fluorinator) of nickel, for carrying out fluorination reactions on uranium and plutonium materials, and a 2-in.-dia Inconel unit (referred to as a converter) intended for hexafluoride-to-oxide conversion studies and PuF_6 thermal-decomposition studies. (See Parts 14 and 15 in this series of reports, noted on p. 4.)

The facility is described fully in ANL-6901. Figure 1 shows the main areas and the location of the two gloveboxes and the instrument panel board. The facility is described below in terms of the following subdivisions:

1. Isolation room
2. Operations room
3. Process-cell area
4. Fan loft (above the facility)
5. Service floor (below the facility).

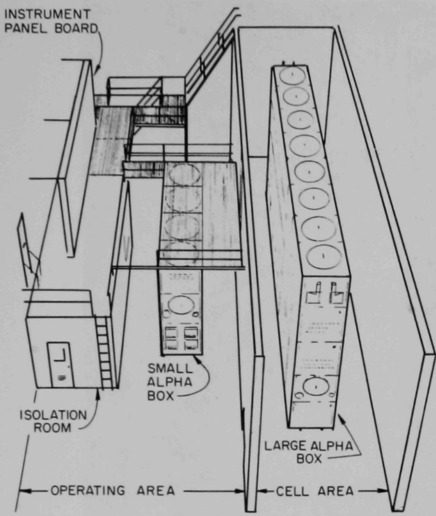

Fig. 1. Engineering-scale Alpha Facility.
ANL Neg. No. 108-5228.

2.1.1 Isolation Room

Entrance to and exit from the facility proper are through the isolation room. The room is equipped with a hand and foot alpha monitor (described in Section 2 of Appendix K); also, the strip recorder for the stack-air radiation detector is located here. The room is used to store the facility personnels' normal outer garments, laboratory coats, and individuals' safety equipment, such as assault masks. As will be detailed later in this manual, the isolation room serves as a control area during most emergency procedures.

2.1.2 Operations Room

The largest area in the facility is the operations room, the bulk of which is taken up by the small glovebox. The rest of the room on the ground level comprises the work area, Lapp pump, refrigeration system, and fluorine storage cabinet. The process control panels (instrument panel board) are located on a balcony overlooking the glovebox work area. There is a glovebox-cover access area above the small glovebox and another one above the process cell; these areas are regarded as part of the operations room.

2.1.2.1 Small Glovebox. The small glovebox (see Sections 2.2.1 and 2.2.2) houses the process scrubber, the converter scrubber, process-gas control equipment, and a bank of AEC filters. A sphincter unit (see Section 3.2.8) provides a means of introducing small items to this glovebox. Material moving in or out of this glovebox can also be passed through an 8-in. bagout port or a 22-in. bagout port located at one end of the glovebox (shown in Fig. 2). Access through the top of the glovebox is provided by four 30-in. bagout ports.

2.1.2.2 Operating Area. Surrounding the small glovebox is a general maintenance and work area. Workbench space and tool and materials storage are provided, and the bulk of out-of-box fabrication takes place here. The fluorine storage cabinet and the distribution system are in this area.

Maintenance of the Lapp pump motor, controls, and primary head is performed at the pump position in the work area. Also located here are the pump controls and the priming system for the secondary loop of the process refrigeration unit.

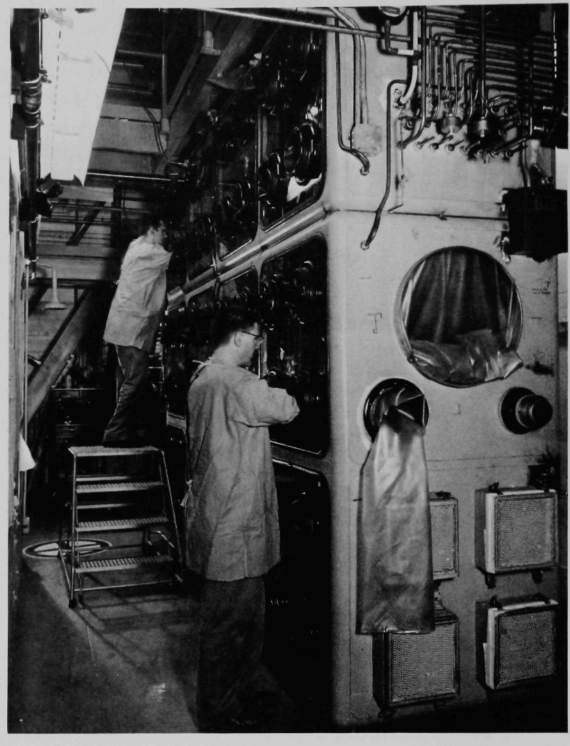

Fig. 2. Small Glovebox. ANL Neg. No. 108-8507.

Accessible in the work area are the supply-valve timer for the P-10 gas (argon-methane purge for alpha-radiation-detection heads) and the automatic valve that controls water feed into the process scrubber.

An overhead, traveling, 3-ton crane serves the work area, the glovebox-cover areas, and the process-control-panel area.

2.1.2.3 Process-control-panel Area (see Fig. 3). Located at the process control panels and the balcony area immediately adjacent to the control panels are a number of safety devices in addition to the process control and recording instruments. The emergency-alarm board, mounted on the main panel, indicates the nature and location of an emergency or an abnormal condition. The master station of the facility intercommunications network is located on the balcony. From this station, personnel are in contact with the isolation room, the process cell, the corridor adjacent to the alpha facility, the service floor, and the fan loft. Other safety items indicate the status of ventilation-system interlocks. A criticality-alarm horn is mounted on the wall directly opposite the process-control-panel area.

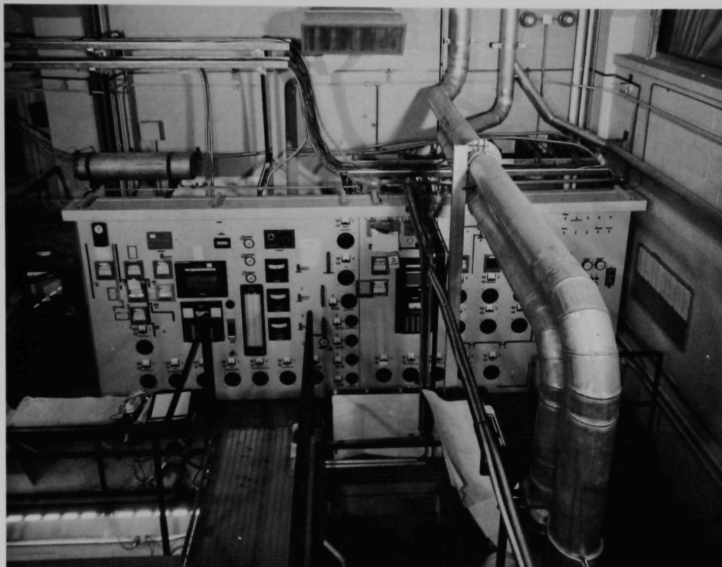

Fig. 3. Process Control Panels. ANL Neg. No. 108-7240.

2.1.2.4 Glovebox-port Access Areas. Both the large and the small gloveboxes have bagout ports allowing access through their ceilings. Bagging operations are performed from a service platform above the small glovebox and from the roof of the process cell that houses the large glovebox. These are ~10 and 20 ft above the work-area floor, so close attention to safety by personnel is warranted.

The constant air monitor (CAM-5) unit and the detector head of the criticality alarm are located in the cover-access area for the large glovebox. These units are discussed in Sections 4.3.1 and 4.3.8 and Appendix L.

2.1.3 Process-cell Area

The process cell is isolated from the work area by a wall of high-density concrete block. Most of the cell interior is taken up by the large glovebox (shown in Fig. 4), which houses fluoride-volatility-process equipment. Operated along both faces of the glovebox are personnel lifts (Fig. 5; two lifts at each face), which provide access to all areas of the glovebox face. Also inside the process cell is the interhalogen supply hood (shown in Fig. 6).

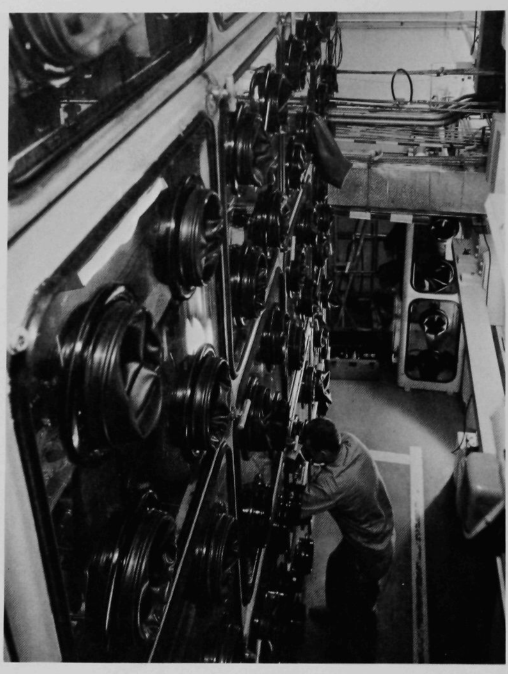

Fig. 4. Large Glovebox. ANL Neg. No. 108-8502.

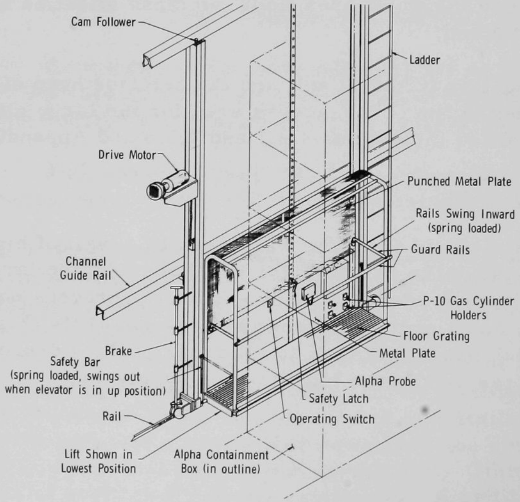

Fig. 5

Personnel Lift for Operations at the Large Glovebox

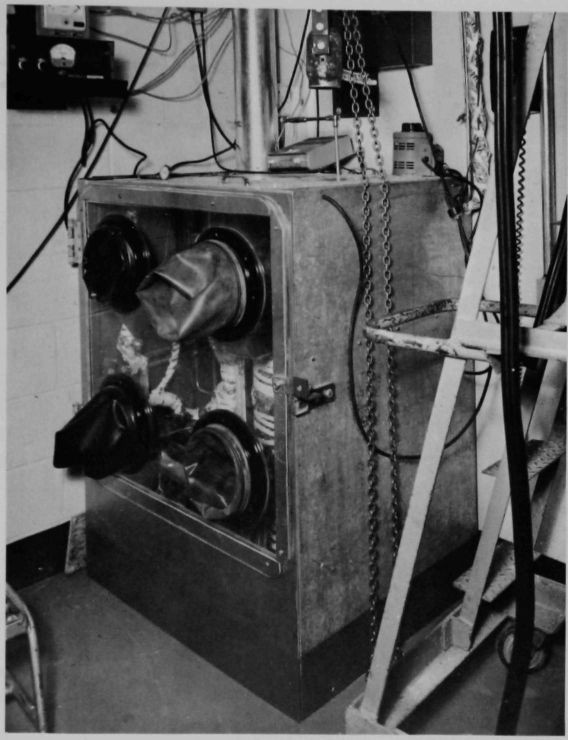

Fig. 6. Interhalogen Supply Hood. ANL Neg. No. 108-8499.

2.1.3.1 Large Glovebox. Within the large glovebox (further described in Section 2.2.1) are the fluid-bed reactor, converter, sorbent traps, hexafluoride cold traps, piping, controls, and miscellaneous equipment. Bagout ports for equipment transfer into the large glovebox are identical to those described for the small glovebox, except that the large box has an additional 22-in. bagout port on the end opposite the end where the other bagout ports and the sphincter opening are located. Eight 30-in. bagout ports provide access through the top of the box.

2.1.3.2 Glovebox Personnel Lifts. Each of the four personnel lifts is mounted on wheels for horizontal movement, which is effected by manually pushing the unit. Vertical movement is hydraulically powered; the elevator platform is locked mechanically when it has been raised to a desired elevation. Once locked in position, the platform safety supports 1000 lb. Experience has proven, however, that the stages can lift no more than ~600 lb. Personnel elevator specifications include the following:

Operation:	Chain and sprocket linkage to hydraulic rams
Platform capacity:	Two men
Platform dimensions:	7 x 2 ft
Platform lock:	Position-type mechanical (spring-loaded pin)
Vertical movement control:	Constant-pressure push button (on platform)
Vertical movement speed:	Approximately 20 ft/min

2.1.3.3 Interhalogen Supply Hood. The interhalogen supply hood (shown in Fig. 6) provides a metered supply of gas to process equipment from a gas-cylinder source. The hood is also equipped with a scale to weigh the cylinder and a heating circuit to warm the cylinder. The hood has been used on different occasions to supply hydrogen fluoride (anhydrous), chloride trifluoride, and bromine pentafluoride.

2.1.4 Fan Loft

The fan loft, located one level above the process cell level, houses the blowers that provide ventilation for the facility, the ventilation scrubber-filter system, and the detection unit of the stack-air monitor system. The ventilation-scrubber pump and solution holding tank (shown in Fig. 7) are located in a corridor at the control-panel level just outside the facility proper. No direct access to the fan loft from the facility is provided so that the fan loft would not be contaminated if the laboratory work areas become contaminated.

2.1.5 Service Floor

The service floor (one level below the isolation room, operations room, and process cell level) can be reached only by leaving the facility. Located on the service floor are the process-gas manifolds (shown in Fig. 8) for the process and service gases (nitrogen, oxygen, P-10 argon-methane mixture, acetylene, and emergency compressed air) and the compressor and chiller of the process refrigeration system.

2.2 Alpha-containment Equipment

The gloveboxes, which are the alpha-containment barriers, are completely sealed off from the room, with the exception of air intakes; the intakes are provided with high-efficiency (AEC-type) filters. The intake filters are a safety measure in the event that above-ambient pressures develop in the box, which would cause some outward flow of air. (Glovebox air is presumed to be contaminated.) The likelihood of overpressurization appears to be very slight.

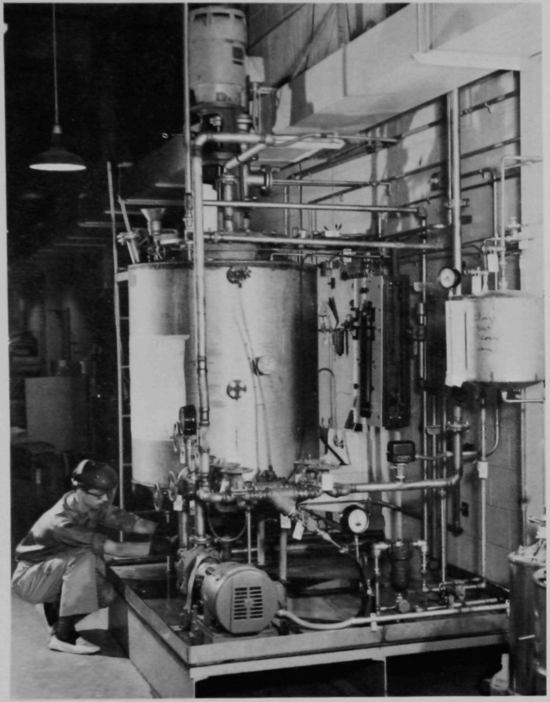

Fig. 7. Circulating System for Ventilation-scrubber Solution. ANL Neg. No. 108-8858.

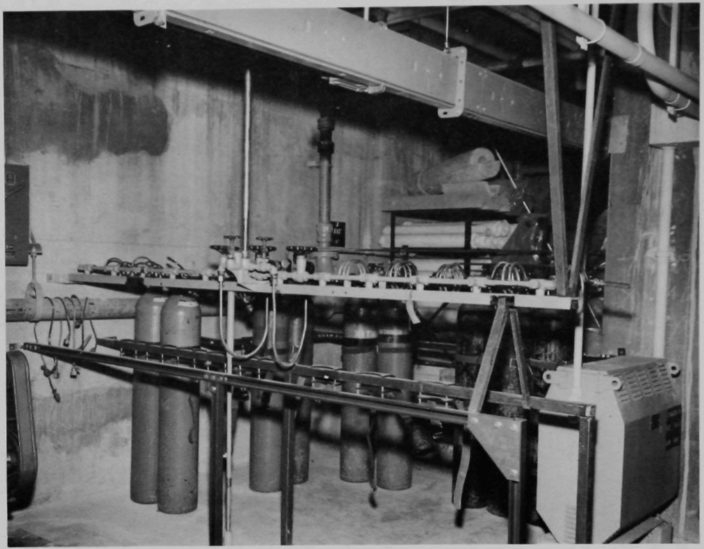

Fig. 8. Process-gas Manifolds. ANL Neg. No. 108-6717.

The ventilation system for these enclosures maintains internal glovebox pressures at a lower value than the external room pressure. This ensures that if the integrity of the enclosure is broken, air will flow into the enclosure through the leak, reducing the chance that contaminants will escape from the enclosure. If, as a result of ventilation-system failure, the enclosure pressure reaches room pressure, the airtight construction of the enclosure would prevent escape of contamination.

Four enclosures in the facility are intended to contain alpha-emitting material:

1. The large glovebox (the large alpha box),
2. The small glovebox (the small alpha box),
3. The Lapp pump enclosure, and
4. The vacuum pump enclosure.

Their descriptions here are general, pertaining only to safety considerations. More detailed descriptions are given in Ref. 5.

2.2.1 Large Glovebox

The large glovebox, which contains the main process equipment, is $17\frac{1}{3}$ ft high, $26\frac{1}{2}$ ft long, and $3\frac{1}{2}$ ft wide. The sides of the box are made of 1/8-in.-thick, cold-rolled steel sheet; the end panels are of 3/16-in.-thick steel. Unistrut channels are welded at critical points on the inside to strengthen the box and facilitate equipment mounting.[6] The windows, 3/8-in.-thick laminated safety glass, are mounted in the framework with neoprene molding (self-sealing weather-stripping) and are sealed with a room-temperature-setting silicone rubber. The volume between any two opposing windows is referred to as a module. The large glovebox, therefore, is eight modules wide and five modules high. The modules have been given a number and letter designation, which is used in defining locations within the glovebox. Additional details of glovebox construction are given in Appendix I.

Four gloves are located in each 3 x 3-ft window. The gloves are Dura-Sol model 8N43032 and Neo-Sol model 6N-1332-58 (both manufactured by the Charleston Rubber Co. of Charleston, South Carolina) or equivalent. Both types are fabricated of seamless, milled neoprene. The Dura-Sol glove, in addition, has a thin synthetic polymer coating that is intended to give longer life as a result of added protection under severe irradiation. This has been confirmed by experience with this facility. Typical glove dimensions are shown in Fig. 9.

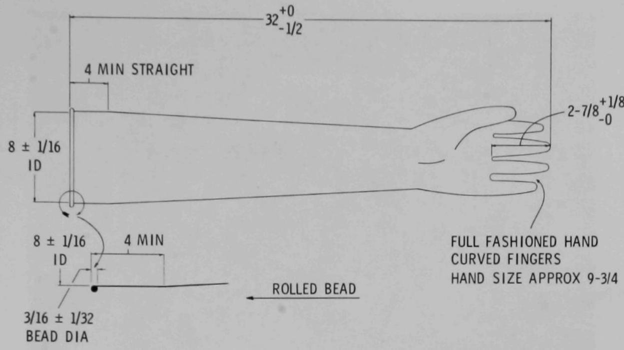

Fig. 9. Glove Dimensions[8]

Airtight seals are provided for the wiring and piping penetrations in the glovebox walls. Canisters containing fiber-glass filters (providing 99.7% removal of >0.3-μm particles) are installed in each pipe or pneumatic tubing line that penetrates the box as a precaution against spread of contamination by dust that accumulates inside the glovebox. In most instances, these canisters are located very near the glovebox wall.

Before being used with plutonium, the glovebox was leak-tested. At 2-in. H_2O positive pressure, the leak rate for the large glovebox (1600-ft^3 volume) was 0.42%/hr. This was considered satisfactory. (Under normal conditions, the glovebox is at ~0.5-in. H_2O negative pressure.)

2.2.2 Small Glovebox

The small glovebox, containing the process scrubber and the converter scrubber, is $10\frac{1}{2}$ ft high, $13\frac{1}{2}$ ft long, and $3\frac{1}{2}$ ft wide (four modules wide and three modules high). The construction and sealing of penetrations are identical to those of the large glovebox.

A 2-in. H_2O positive-pressure leak test of the small glovebox (500-ft^3 volume) indicated a leak rate of 0.07% per hour, which was satisfactory. (Normal-condition pressure is ~0.5-in. H_2O negative pressure.)

2.2.3 Lapp-pump Enclosure

The Lapp pump enclosure (shown in Fig. 10) is essentially a glovebox of the same construction as described above. It is 7 ft high, $3\frac{1}{2}$ ft long, and 2 ft wide (one module long, two modules high, and one-half module wide).

This enclosure is connected to the large glovebox by a welded, leak-tight ventilation duct. The enclosure (~47-ft^3 volume), which was leak-tested at the same time as the large glovebox, normally maintains the same internal pressure as does the large glovebox (~0.5-in. H_2O negative pressure).

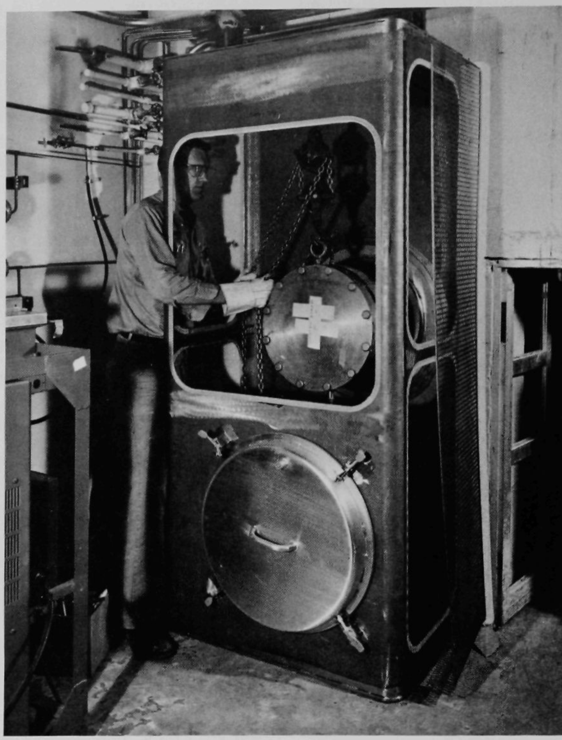

Fig. 10. Lapp-pump Enclosure. ANL Neg. No. 108-7245.

2.2.4 Vacuum-pump Enclosure

The vacuum-pump enclosure (shown in Fig. 11) is built into the cement-block wall that separates the operating area from the process-cell area. Aluminum sheet (rather than steel) frames are mounted on both sides of an opening (3 ft wide, $4\frac{1}{2}$ ft high) in this wall. One window is mounted in each of the two frames in the same manner as is described for the gloveboxes. A process vacuum pump is housed in the 2-ft-deep enclosure (~27 ft^3 volume). Normal-condition pressure inside the enclosure is maintained at ~0.7-in. H_2O negative pressure. The vacuum-pump exhaust vents to the large glovebox.

2.3 Ventilation System

The room-ventilation scheme provides that ventilation air move in a once-through flow path from the least contaminated to the most contaminated areas. Ventilation air follows one of five paths through the room and gloveboxes, as shown in Fig. 12.

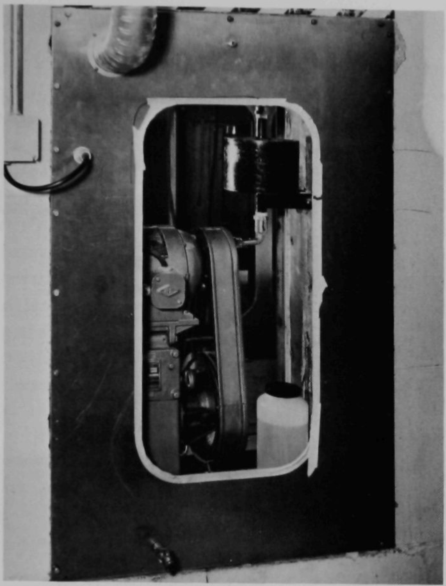

Fig. 11

Vacuum-pump Enclosure.
ANL Neg. No. 108-7242.

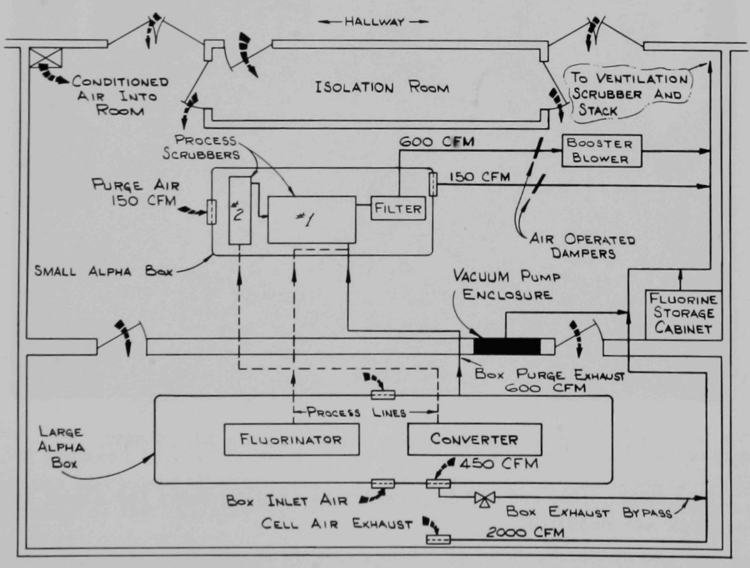

Fig. 12. Room Ventilation-air Pattern. (The box exhaust bypass is used only when pressure in the large alpha box is not maintained within specifications.)

2.3.1 Room Ventilation

Approximately 3000 cfm of air enters the room from two inlets located on the wall above the control panels and from the corridor adjacent to the facility through louvers in the facility's doors. A negative pressure differential of 0.02 in. of water is maintained between the room and the corridor. Part (~1000 cfm) of the air is distributed by balancing controls to the small alpha box, fluorine storage cabinet, vacuum-pump enclosure, interhalogen-supply enclosure, and large alpha box. The remaining room air (~2000 cfm) is exhausted through two ducts located in the process-cell area and is recombined with the side streams from the enclosures. The combined air stream is passed through a horizontal-spray ventilation-air scrubber and high-efficiency filters (six in parallel) before being discharged to the stacks; this equipment is located in the fan loft. Normal operating conditions for components of the ventilation-air scrubber (shown in Fig. 13) are given in Section 4.3.2.

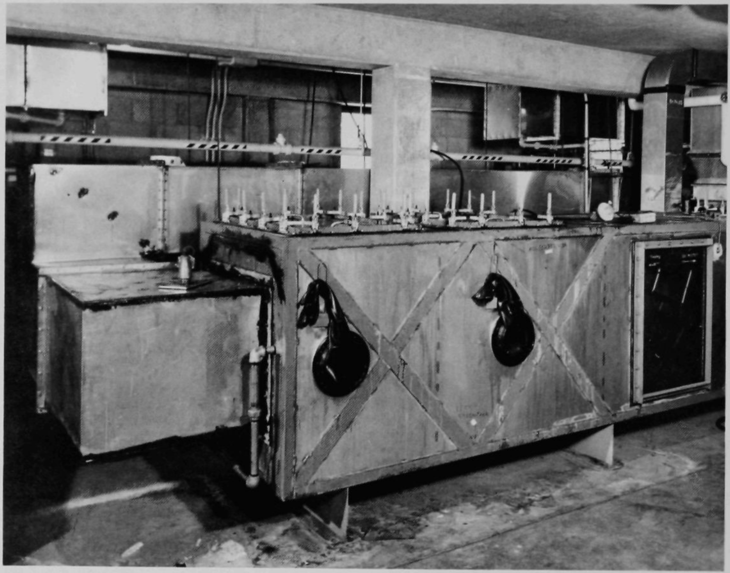

Fig. 13. Ventilation-air Scrubber System. ANL Neg. No. 108-8857.

The filter effluent air is monitored continuously for alpha activity by the stack air monitor.

2.3.2 Ventilation of Large Glovebox

The large glovebox, which houses most of the plutonium-handling process equipment, is maintained at its normal 0.5-in. H_2O negative pressure by exhausting approximately 500 cfm of ventilation air. The air entering the glovebox is filtered by passage through two parallel, 24-in.-square AEC-type filters. On leaving the box, the air is passed through the process scrubber (located in the small glovebox) and then through three AEC filters in series (also located in the small glovebox) before being combined with the room exhaust air. The process-scrubber system is shown in Fig. 14. Normal operating conditions for process-scrubber components are given in Section 4.3.2.

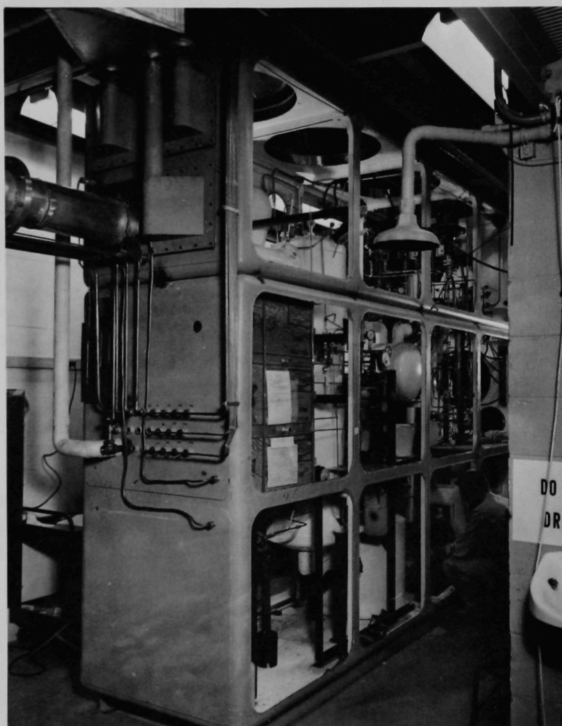

Fig. 14. Process-scrubber System. ANL Neg. No. 108-7241.

A booster blower is used to overcome the pressure drop across the process scrubber-filter system. Discharge from this blower is to the main plenum of the ventilation-air scrubber (located in the fan loft).

The process scrubber is intended mainly to humidify the air from the large glovebox (also to humidify the process off-gas during runs). Humidification promotes hydrolysis of any contained UF_6 or PuF_6 to particulate oxyfluorides. Particulate material is then efficiently collected on the AEC-type filters.[9] Room-environment air is maintained at a relative humidity of 30-40%. Hydrolysis of released hexafluorides will, most likely, be initiated in the large glovebox, and the solids produced will be deposited on equipment surfaces. This minimizes entrainment of contaminants to the process-scrubber system (and the small glovebox).

If pressure in the large glovebox reaches a preselected value, a bypass duct opens automatically to exhaust an additional 450 cfm of air. The duct, which can be operated manually, bypasses the process scrubber and associated AEC filters; the air passes through a high-efficiency filter as it leaves the large glovebox, joins the ventilation air exhausted from the room, and is scrubbed in the ventilation-air scrubber. Control of glovebox ventilation is discussed in Section 4.3.2.

2.3.3 Ventilation of Small Glovebox

The small glovebox, which is not expected to become highly contaminated, is ventilated with 150 cfm of air (purge air) from the room. This air is drawn through 1-ft-square AEC high-efficiency filters upon entering the glovebox and is filtered again on leaving. This exhaust air is combined with the room-exhaust air upstream of the ventilation-air scrubber-filter system.

2.3.4 Ventilation of the Fluorine Storage Cabinet and Vacuum-pump Enclosure

Since the fluorine storage cabinet (shown in Fig. 15) is essentially an open hood, no filters impede the flow of ventilation air. Approximately 100 cfm of air is exhausted from the fluorine cabinet and combined with the exhaust air from the small glovebox.

The vacuum-pump enclosure (shown in Fig. 11), designed to contain alpha contamination, has an air exhaust rate of 50 cfm. The air from this enclosure combines with the exhaust stream from the small glovebox, upstream of the ventilation-air scrubber-filter system.

3. GENERAL SAFETY PROCEDURES

3.1 Personnel Considerations

The alpha facility has been designed to meet reasonable safety standards by minimizing the hazards associated with the fluoride-volatility process. To realize the full benefit of the installation, however, personnel must be thoroughly familiar with its workings and intent and be safety conscious. This manual serves as a guide for accomplishing that end.

Fig. 15. Fluorine Storage Cabinet. ANL Neg. No. 108-6325.

The general safety procedures presented here must be followed conscientiously as a normal part of all operations in order to maintain safe working conditions in the facility. (Emergency procedures are discussed in Section 4.) Written operating procedures and check lists, which have been prepared for many operations, must be followed meticulously.

3.1.1 Access to the Facility

Only authorized personnel, whose names are posted on the door to the isolation room, are permitted free access to the facility. All other persons must use the telephone in the corridor outside the isolation room to obtain permission to enter. Entry to the facility, under normal conditions, should only be made through the isolation room, where radiation monitoring equipment (discussed in Section 2 of Appendix K) is available. Hands, feet, and any object carried into the facility must be monitored for alpha activity upon entering and leaving the facility.

When turned on, a red warning light in the isolation room signals that unusual or hazardous operations (e.g., filter bagout, large-bag changes, glove changes) are in progress in the facility. This light also indicates an emergency condition. No person (regardless of authorization) may enter the facility when this light is on until he has been informed of the nature of the condition and has gained permission to enter (via the corridor telephone).

Normal exit from the facility is also through the isolation room. Emergency exits are located on the operations-room and the instrument-panel-area levels; only the former exits are fitted with crash bars.

3.1.2 Clothing and Equipment Requirements

Everyone entering the facility must wear safety glasses and ANL safety shoes or shoe covers. The normal clothing for personnel working in the facility is laboratory-furnished work clothes and safety shoes. For working at a glovebox, a lab coat, taped at the wrists, and surgical gloves are also required. Visitors in street clothes should wear lab coats when touring the cell area. The lab coats are to be left in the isolation room when personnel leave the facility. Hard hats are to be worn when the overhead crane is in use. Additional details on personnel protective procedures are given in Section 9 of Appendix E.

3.1.3 Radiation Safety Requirements

Operating personnel are required to wear pocket dosimeters and neutron-sensitive film badges (described in Appendix K) when working in the facility (see Section 4 of Appendix C). All personnel, equipment, and supplies must be checked for alpha contamination upon entering and leaving the facility. Assistance from Radiation Safety (Industrial Hygiene and Safety Division, ANL) personnel should be obtained for monitoring objects that are likely to be contaminated or are difficult to survey. Radiation Safety personnel are to be notified in all cases of personnel contamination.

In the event of airborne contamination in the room or cell area, only persons with positive-pressure respirators (such as Scott Air Paks) are to remain in the facility (including the isolation room). Assault masks should be worn only on a temporary basis.

The room-air monitor (CAM-5) and the stack monitor must be in operation at all times. Radiation monitoring equipment is serviced by Radiation Safety personnel. The filters for the room-air monitor and the stack monitor are changed weekly or, if there is an indication of unusual activity buildup, more often. The filter for the stack monitor is routinely counted to determine the long-half-life activity. Calibrated sources are provided at each alpha monitor so that radiation levels can be checked at any time by operating personnel.

Plutonium-containing materials (such as bagged samples) must be sealed in airtight secondary containers when taken from the facility. Radiation Safety personnel must be notified of large movements of plutonium-containing material. (Control of plutonium movement is described in Sections 3.2.4 and 3.2.10.3.)

Eating is not permitted in the facility, and smoking is permissible only in the isolation room (see Section 3 of Appendix C).

3.1.4 Maintenance of Safe Working Conditions

An overall responsibility for maintaining safe working conditions in the facility is assigned to specific individuals on a monthly basis, as described in the following paragraphs.

3.1.4.1 Engineer of the Month (EOM). The engineer of the month (EOM) is given the responsibility for coordinating the work in the facility to the extent that personnel working independently do not create unsafe conditions for each other. The EOM is also responsible for evaluating entries in the facility logbook that may require action. During shift operation, the shift supervisor has these responsibilities.

3.1.4.2 Technician of the Month (TOM). The technician of the month (TOM) is responsible for periodically checking the facility systems (such as scrubbers, alarm panels, radiation detection equipment, and ventilation systems) for proper operation. The equipment to be checked and the acceptable operating limits are specified on data sheets. Any deviation from the accepted limits is entered in the facility logbook and brought to the attention of the EOM. Operational responsibility is shared by the technicians and staff, but major responsibility falls to the EOM. Therefore, the EOM must be kept informed of the activities in the facility.

Equipment items requiring attention or maintenance are referred to the Facility Area Safety Coordinator, a single individual (in this case, a chief technician) who has the responsibility for implementing the maintenance or other work. The individual does this himself or coordinates the work of support personnel.

This EOM-TOM system, with its rotating-personnel feature, helps maintain a safe climate and provides all facility personnel with an opportunity to gain familiarity with the operation of all facility systems.

3.2 Operational Considerations

3.2.1 Glovebox Work Rules

The rules for safe performance of work in the gloveboxes are as follows:

1. At least two operating personnel must be present in the facility when work is being done in the glovebox or process cell area.

2. A lab coat, with the sleeves taped at the wrists, and surgical gloves must be worn when the hands are in the glovebox gloves.

3. The hands must be surveyed for alpha activity each time they are withdrawn from the glovebox gloves.

4. No glass, sharp objects, or flammable liquids may be put inside the gloveboxes.

5. Assault masks must be worn when glovebox gloves are being changed or when material is being bagged through 22- and 30-in. ports. Radiation safety personnel must be present for these operations. Bagging operations through 8-in. ports and sphincter operations can be performed without masks or without the presence of Radiation Safety personnel.

6. All glovebox glove changes must be logged in the facility logbook and marked on the glove-location chart (which is maintained in the isolation room).

7. When an oxyacetylene torch is being used inside one of the gloveboxes, a second person must observe the work. The ANL Fire Department will provide standby service upon request.

8. The Fire Department must be notified before any operation (torch work, process-equipment heatup, etc.) is initiated that might cause a false fire alarm. As discussed in Section 4.3.4, this rule has been found necessary because of the proximity of process equipment to the heat-sensitive fire-alarm detectors. Too rapid heatup of process equipment has triggered the fire alarm. If the alarm is activated, the Fire Department should be immediately contacted and asked to postpone its response until facility personnel determine whether the alarm is false. If no evidence of fire can be found, the alarm is termed false. The Fire Department is informed of this fact and advised to ignore the alarm.

3.2.2 Maintenance Work Rules

All proposed maintenance work must be approved by the EOM or shift supervisor, who makes sure it does not conflict with other work in the facility.

Work that involves disconnecting lines or opening equipment, either inside or outside the glovebox, should be carefully considered as to the likelihood of releasing radioactive material. Appropriate measures should be taken to prevent or contain any releases. When lines outside the glovebox (other than gas cylinder connections) are disconnected, positive-pressure respiratory equipment must be worn and radiation monitors must be on hand in the event that some radioactive material has backed up through in-line filters.

3.2.3 Rules for Handling Fluorine, HF, and Interhalogens

The general hazards involved in handling fluorine and fluorine compounds are described in Section 1.3. The following specific rules must also be followed in the facility:

1. Two people must be present when fluorine, HF, or interhalogens are being used in the facility.

2. Two people, wearing fluorine-resistant, protective clothing (including coats, gloves, and face shields), must be present when supply cylinders are being changed or when lines are being disconnected.

3. After fluorine or interhalogen supply connections are made, they should be checked with starch-iodide paper for major leaks and then pressure leak-tested.

Other precautions in handling or storing fluorine are given in Appendix F.

3.2.4 Plutonium-handling Regulations

The following regulations are posted in the isolation room:

1. Maximum allowable plutonium inventory for the facility is 2000 g.

2. The posted value for plutonium inventory in the facility shall always be current. (See Section 3.2.10.)

3. All transfers of plutonium-containing materials to or from the room, including suspect materials, must be logged in a plutonium logbook. A transfer must have the approval of the room supervisor (EOM).

4. Process and glovebox auxiliary water systems may be connected to the house water supply only during filling operations.

5. All facility operations are to be carried out with the approval of the room supervisor (EOM).

6. No more than 200 g of plutonium may be accumulated in aqueous solutions (such as hydrolysis samples) in any glovebox.

7. No more than 200 g of volatile plutonium compounds (PuF_6) may be heated above the boiling point at any one time.

3.2.5 Changing Gloves of Gloveboxes

A glove is changed by installing a new glove over the glove port on the outside of the glovebox and removing the old glove to the inside of the glovebox. The procedure, depicted in Fig. 16, is as follows:

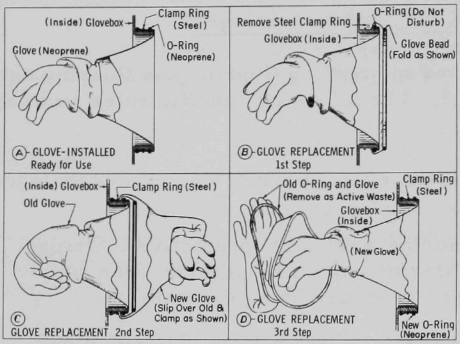

Fig. 16. Glove-replacement Procedure.
ANL Neg. No. 106-2058. Rev 1.

1. Check the new glove for flaws. Secure the services of Radiation Safety personnel to monitor the glove-changing operation. Assault masks must be worn during the glove-changing operation. Personnel not involved in the operation must leave the area until the glove change is complete. The red warning light in the isolation room should be on while the operation is in progress.

2. Inspect the old glove to make sure it is sealed with a clamp and an O ring. Remove the glove clamp and fold back the glove bead, being careful not to disturb the O ring. The glove mounting under the bead may be contaminated. Before continuing, check this portion of the mounting for alpha activity.

3. Slip the new glove over the old one. Position the glove so that the thumb is at the top. Clamp the glove in place using the clamp removed in step 2.

4. Reach into the glovebox through an adjacent gloveport, and remove the old glove and O ring, discarding them as waste.

5. Install a new O ring over the new glove and mounting ring.

6. Survey the area around the glove mounting for alpha activity.

7. Record the glove change in the facility logbook and on the glove-location chart in the isolation room.

8. Notify facility personnel that the operation is complete, and turn off the red warning light.

3.2.6 Bagging Material into a Glovebox (and Bag Changing)

Normally, material is bagged into a glovebox by placing the material inside an existing bag, then mounting a new bag by the same procedure as is used in glove changing (described above). Material transfer pouches (bags) are described in Appendix J.

Alternatively, the sealing technique shown in Fig. 17 can be used. Specifications for a typical dielectric heat sealer are given in Table I.

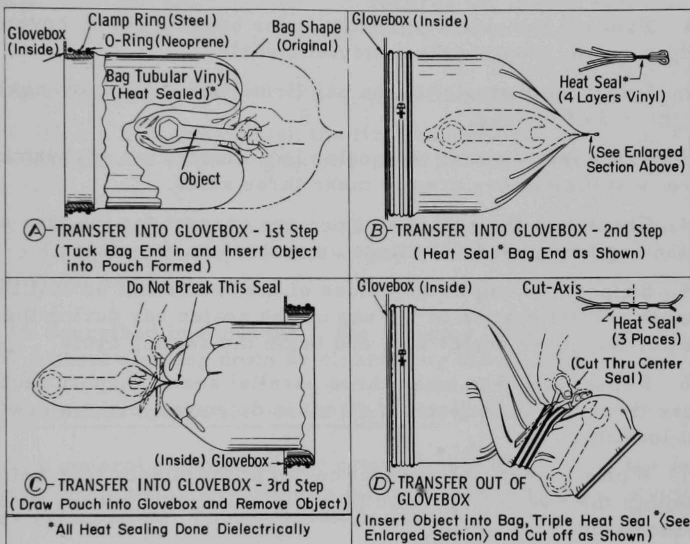

Fig. 17. Bagging Procedures. ANL Neg. No. 106-2056 Rev. 1.

TABLE I. Typical Dielectric Heat Sealer

(Data supplied by J. A. Calanan Co., Chicago, Ill.)

Name:	4-kW high-frequency generator and mandrel press unit
Use:	Sealing of polyvinyl chloride plastic bags
Power source:	208-230 V ac, 60 Hz, single phase
Frequency generated:	27 MHz
Generator mounting:	Four-wheel cart
Mandrel size:	Press length of 21 in.
Press ram size:	Air-cylinder diameter of 3 in.

When an 8-in.-dia bag is changed, the assault mask need not be worn and facility personnel may perform their own alpha-contamination check. When larger bags (22- and 30-in.-dia bags) are changed, an assault mask must be worn and Radiation Safety personnel must be present.

3.2.7 Bagging Material Out of a Glovebox

Use the following procedure, involving a dielectric heat sealer, in removing material from gloveboxes (see Fig. 17):

1. Prepare the object or material for bagging out by covering all sharp edges and by labeling the material clearly.

2. Insert the material in the bag (from inside the glovebox), working it out to the end of the bag.

3. Place the bag over the sealer bar; smooth out any wrinkles; check that there is sufficient bag area to make three seals.

4. Check that the sealer settings are correct for the size and thickness of the bag being used. (Settings are posted on the sealer.)

5. Support the bag at both sides of the sealer bar so that there will be no stress on that portion of the bag on the sealer bar during the sealing cycle; lower the upper sealer bar, and begin the sealing cycle.

6. Repeat step 5 to make three parallel seals; inspect each seal to make sure there are no defects; if a seal is defective, make a new seal at a different location.

7. With scissors, cut down the center of the middle seal, being careful to stay within the "welded" portion (see Fig. 17); avoid cutting through any obvious inclusions in the seal.

8. Survey the cut portion of the seal, the scissors, and the sealer bar for alpha activity. Tape the cut end of the removed bag section; label the bag, and place it in a secondary container.

3.2.8 Material Transfer into a Glovebox through a Sphincter

The sphincter unit is a tunnel-like assembly, built into one end of each glovebox (as shown in Fig. 18). The inside of the opening is lined with resilient, circular seals (oil-seal rings). When a 4-in.-dia aluminum sphincter can is inserted into the opening, the can becomes essentially a plug that maintains the airtight integrity of the glovebox.

Small items to be transferred into the glovebox are placed inside the can that is in the sealing mechanism. This can, with its contents, is then displaced by pushing a second can into the opening. Under no circumstances should a can be withdrawn from the sphincter sealing mechanism to the exterior of a glovebox. Once a can is in the sealing mechanism, it is considered contaminated with alpha activity.

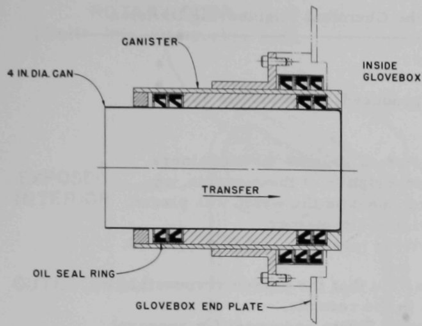

Fig. 18. Sphincter Assembly

Use the following procedure in transferring material into the glovebox via the sphincter-can system:

1. Check the replacement can for any nicks or galls that might damage the seal.

2. Lift the safety latch that secures the in-box end of the can within the sealing mechanism.

3. Place the item being transferred inside the in-place can.

4. Use a new can to push the first can into the glovebox; do not push the leading end of the replacement can past the plane of the safety latch.

5. Reach into the glovebox and remove the first can from the sphincter mechanism. Replace the safety latch, and push the replacement can against the latch bar.

As described in Appendix I, the canister (shown in Fig. 18) may be replaced without shutting down or cleaning up the glovebox.

3.2.9 Regulations for Active-waste Disposal

The general regulations for active-waste disposal in the facility are generally the same as those for other operations of the Chemical Engineering Division. These regulations are listed in Table II.

Disposal of plutonium-alpha contaminated waste generated in a glovebox operation requires specific regulations, which are discussed in the following sections.

3.2.9.1 Dry Active Waste (DAW). All material used in the operation of the facility is considered alpha suspect. During operations, a large amount of dry, active waste (DAW) is generated. This waste falls into two categories.

In the first category is material that is soft and easily compressible, such as discarded surgical gloves, tape, tissue, paper, and paper containers. This material is placed in Blickman DAW cans (shown in Fig. 19) or in large cardboard cartons.

The second category of waste includes material that is rigid and noncompressible or that would, if compressed, present a hazardous situation.

TABLE II. Waste-disposal Regulations of the Chemical Engineering Division

General Suggestions

1. Plan for waste disposal BEFORE the waste is produced. Guidance is available from Radiation Safety personnel.
2. Obtain the necessary containers.
3. Label all containers of active or hazardous wastes as soon as the containers are placed in use. The label should include a description of the contents, an indication of the type and intensity of the hazard, the date the waste was placed in the container, and the name of the person using the container.
4. Before disposing of equipment listed in the Division inventory, get the approval of the Divisional Property Representative.
5. Where special materials are involved, make certain that the person responsible is informed and that suitable entries are made in the records.
6. Before using clear-water drains, contact Radiation Safety personnel for approval.
7. For your own convenience, keep this chart posted in a handy location.
8. If in doubt about any waste-disposal problems, contact Radiation Safety personnel.

Methods of Disposal

Type of Waste	Inactive	Suspect and Low-level Active, <50 mR/hr	High-level Active, >50 mR/hr
Solid combustible (paper, wood, etc.)	A	B	C
Floor sweepings	B	B	C
Solid noncombustible (metal, ceramics, etc.), Glass bottles (acetone, ether, etc.--fill with water; then empty before depositing in waste can)	D	B	C
Acid bottles (rinse thoroughly)	E	B	C
Organic liquids (oil, carbon tetrachloride, acetone, etc.)	F	F	G
Aqueous solutions	H	K	K
Hazardous materials (mercury, cyanides, lead, beryllium, pyrophoric materials, etc.)	J	G	G
Pressurized spray cans (empty can first)	D	G	G

A: Deposit in wastepaper basket or in GI can marked "Combustible Waste,"

B: Place in Blickman DAW can (Fig. 18); if alpha active, use the can marked "alpha"; if beta-gamma active, use the can marked "beta-gamma"; if both, use the "alpha" can. If too large for the Blickman can, contact Radiation Safety for a proper container.

C: Contact Radiation Safety personnel. Place waste in a shielded pot. Bring the pot to the waste, not the waste to the pot.

D: Deposit in GI can marked "Noncombustible."

E: Rinse thoroughly and deposit in GI can marked "Acid Bottles."

F: Place in metal drums provided in laboratories or in "Organic" drum. Make an appropriate entry on the log sheet attached to the scale. For disposal of a filled metal drum, follow procedure J; do not overfill containers.

G: Contact Radiation Safety personnel for information.

H: Small amounts of many aqueous solutions may be flushed down the laboratory drains. However, to dispose of chlorides, fluorides, and large amounts of corrosive acids, follow procedure K.

I: (1) Call Reclamation for a suitable container. (2) Enter on Form PS-38 (obtain from Reclamation or Radiation Safety) all additions to the container. (3) When the container is full, prepare three copies of PS-38, sign all three, and send them to the Reclamation Office. Reclamation personnel will arrange for pickup of the container. (4) If complete information is not available on the waste, obtain appropriate analyses. Keep organic and aqueous solutions separate.

J: Complete Form PS-38, and forward the form to Reclamation personnel. They will arrange for a pickup.

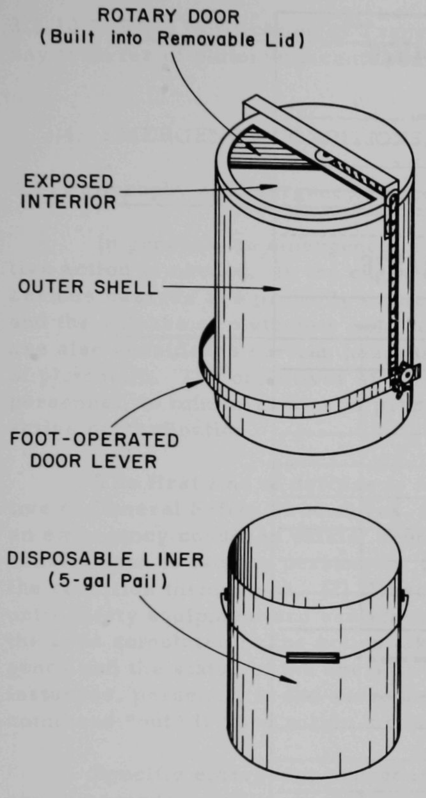

Fig. 19. Blickman DAW Can

Examples of the former are metallic objects and material made of glass or hard plastic; an example of the latter is material that is primarily waste bagged out of the gloveboxes for disposal. Black iron, 55-gal drums are provided in the facility for disposal of waste in the second category.

3.2.9.2 Liquid Active Waste (LAW). Liquid active waste (LAW) is extremely difficult to handle and store. Of prime importance is the fact that water is a neutron moderator. This makes it necessary to minimize the plutonium concentration in aqueous solutions. LAW samples must be kept separate from DAW, especially DAW containing large amounts of plutonium.

LAW bagged out from the gloveboxes is prone to leak from containers. Most of the liquid material is either acidic or alkaline, and either will attack bag material. Rapid disposal of this waste is essential, and secure secondary containment is mandatory. LAW should be stored in separate 55-gal, black iron drums, kept isolated from DAW drums or containers.

3.2.10 Plutonium Inventory Records

3.2.10.1 Plutonium Inventory Logs and Postings. The EOM must enter in the plutonium log any movement of plutonium-containing material into and out of the facility. He must also update the inventory signs to maintain a balanced fissionable-material inventory.

3.2.10.2 The Sample-card File. A numbered sample card (shown in Fig. 20) is prepared for each sample and each quantity of bulk material in a container resulting from process operations, whether the material is to be analyzed or not. The weight, description, location, neutron count, and estimated plutonium concentration are entered on the card. The disposition of the material is later noted on the sample card, along with EOM approval.

F 14576

Run ______ Date ______ Time ______

Requested by ______

Description ______

______

Analyses requested ______

Run #	F 14576	
Date:	Taken by:	Time:

	Anal.	Est.	Anal.	Est.
aqueous				
organic				
solid				
very hot				
active				
nat. U				
unknown				
inactive				
alpha				
beta				
gamma				
Rad. Survey:				

Approximate concentration of other components of this sample:

______

Results to: Location:

Run #: ______ **F 14576**

Date: ______

Description: ______

Results to: ______

Lab. Location: ______

Run #: ______ **F 14576**

Date: ______

Description: ______

Results to: ______

Lab. Location: ______

Fig. 20
Sample Card

3.2.10.3 EOM Notification of Transfer of Plutonium. The EOM must approve any transfer of plutonium-containing material (into or out of the facility).

4. EMERGENCY CONDITIONS, DETECTION, AND PROCEDURES

4.1 Philosophy of Emergency Procedures

In general, an emergency is a condition in which immediate corrective action is needed. In the engineering-scale alpha facility, the most serious hazards are probably criticality (defined in Section 4 of Appendix A) and the release of plutonium outside the gloveboxes. Fires and explosions are also considered serious hazards, since they may result in the release of plutonium. The objectives of emergency procedures are to protect personnel, to minimize loss of property, and to prevent the spread of radioactive contamination.

The first line of defense is to prevent such emergencies (the objective of General Safety Procedures, Section 3 of this report). However, once an emergency condition exists, several alternative courses of action are usually open to facility personnel: (1) Personnel may attempt to handle the condition themselves. (2) Personnel may temporarily leave the area until safety equipment and assistance are obtained. (3) Personnel may leave the area completely. The action taken depends on the nature of the emergency and the status of the operations in progress at the time. In all instances, personnel in the surrounding area should be alerted. The oral command "out" is used within the facility as a signal to evacuate.

Specific emergency procedures established for use in the facility are in accordance with general emergency procedures in effect for the Laboratory and the Chemical Engineering Division.

Emergency procedures described in this section are those that would be followed if operating personnel were present in the facility. Detection of off-shift emergency conditions is the responsibility of maintenance and plant-security personnel. An emergency card (posted outside the facility in the building corridor) lists the names and phone numbers of personnel responsible for operation of the facility. Off-shift personnel who are responsible for surveillance have instructions to notify these people in case of an emergency.

4.2 Emergency Shutdown Procedure

Emergency shutdown procedures for both the fluorinator and the converter systems have been established. These involve closing a minimum number of key valves and cutting off power to a minimum number of key items. These procedures are instituted only if the emergency condition is such that personnel safety does not require immediate evacuation. The procedures are posted at the appropriate control panels.

If a criticality incident occurs, all personnel must evacuate the building immediately, regardless of process conditions. Operating personnel should become familiar with the emergency evacuation routes established by the Divisional Safety Committee. If airborne radioactivity or toxic gases have been released, personnel should move to a safe area and get the proper safety equipment before returning to take corrective action.

4.3 Emergency Alarms

Associated with the facility are several alarm systems. In addition, there are building and site-wide alarms. All operating personnel should be able to distinguish the types of alarm by sound. In general, safety and emergency systems have distinctive alarm sounds, while most process alarms have the same sound (in the case of the facility, a horn).

Table III lists the alarms and summarizes recommended action to be taken during operating and nonoperating periods in response to various emergency alarms in the facility. Emergency conditions that warrant immediate evacuation of the building are criticality, major fires, gross release of activity, and gross release of toxic, hazardous chemicals.

The various alarm systems are discussed in more detail below. The purpose of each alarm is stated, and the system is described.

4.3.1 Constant Air Monitor

A constant air monitor (CAM-5, described in Section 3 of Appendix K) measures the levels of radioactivity in the room air of the facility. It alarms personnel if radioactive particulate solids are released. The monitor air intake is from the room and cell exhaust duct.

Monitoring of air for plutonium or uranium is complicated by the presence of natural radioactivity (radon, thoron, and other decay products from the earth's crust) in the building air. In consideration of this problem, the CAM-5 continuously measures the ratio of beta-gamma to alpha activity, as well as the radiation level of the dust collected on the filter. The ratio of beta-gamma to alpha for natural radioactivity is about 2:1. This ratio changes if long-half-life alpha or beta-gamma material is deposited on the filter of the detection unit.

The CAM-5 sounds a continuous bell if the beta-gamma level on the filter becomes high in proportion to the amount of alpha radiation present. It sounds a continuous buzzer when the alpha level becomes proportionately high with respect to the beta-gamma radiation.

TABLE III. Actions To Be Taken in Response To Alarms in the Alpha Facility

Alarm	Sound	Action To Be Taken: Operating Periods	Action To Be Taken: Nonoperating Periods
Constant air monitor (CAM-5)		1) Hold breath and evacuate room. 2) Return with Scott Air Pak to shut down process run. 3) Notify Radiation Safety.	1) Hold breath and evacuate room. 2) Notify Radiation Safety.
Beta-activity release	Continuous bell		
Alpha-activity release	Continuous buzzer		
Glovebox ventilation control	Intermittent bell	1) Hold breath and evacuate room. 2) Return with Scott Air Pak to investigate and shut down process run (if necessary). 3) Notify Radiation Safety.	1) Hold breath and evacuate room. 2) Notify Radiation Safety.
Stack air monitor	Buzzer	1) Hold breath and evacuate room. 2) Return with Scott Air Pak to shut down process run. 3) Find source of and stop activity release. 4) Notify Radiation Safety.	1) Hold breath and evacuate room. 2) Notify Radiation Safety. 3) Return with Scott Air Pak to find source of and stop activity release.
Heat-detection alarm (fire)	Bell and buzzer	1) Evacuate room; dial the laboratory emergency phone number if a fire is known to exist. 2) If heat-up of equipment is in progress, and alarm may be false, evacuate room, call the Fire Department, advising them to postphone response until the glovebox condition is checked. 3) Return to room with assault masks and quickly check for fire. 4) If a fire is found, evacuate room and inform the Fire Department about the fire. 5) If fire is minor, return to room with Scott Air Paks and attempt to extinguish it. 6) If fire is major, call the laboratory emergency phone number and advise evacuation of the building. Prepare to direct Fire Department personnel to the scene.	
Personnel alpha counters	Increase in audible count	1) Advise other personnel of condition by calling "OUT." 2) Contaminated personnel hold breath and move to area of maximum air flow (such as cell doors). 3) Other personnel evacuate to the isolation room, check themselves for contamination, don assault masks, and take assault masks to contaminated personnel. 4) Notify Radiation Safety. Radiation Safety will conduct a complete survey and advise a course of action.	
Process abnormal alarms	Horn	Take appropriate action to correct the abnormal condition.	
Electrical-power overload alarm	Bell	1) Reduce electrical-power utilization. 2) Reset the alarm and the circuit breaker.	
Criticality	Intermittent horn	EVACUATE BUILDING IMMEDIATELY	
Building evacuation	Siren	1) Shut down the process (if the nature of the emergency permits). 2) Evacuate the building.	Evacuate the building.
Hydrogen detector	Horn	1) Shut off hydrogen supply. 2) Turn off electrical circuits to the gloveboxes.	1) Shut off all supplies of flammable material (hydrogen, acetylene, etc.). 2) Turn off electrical circuits to gloveboxes.

The instrument panel (shown in Fig. 21) for the unit is located in the building corridor outside the facility. The alarm bell and horn are mounted on the south wall of the facility.

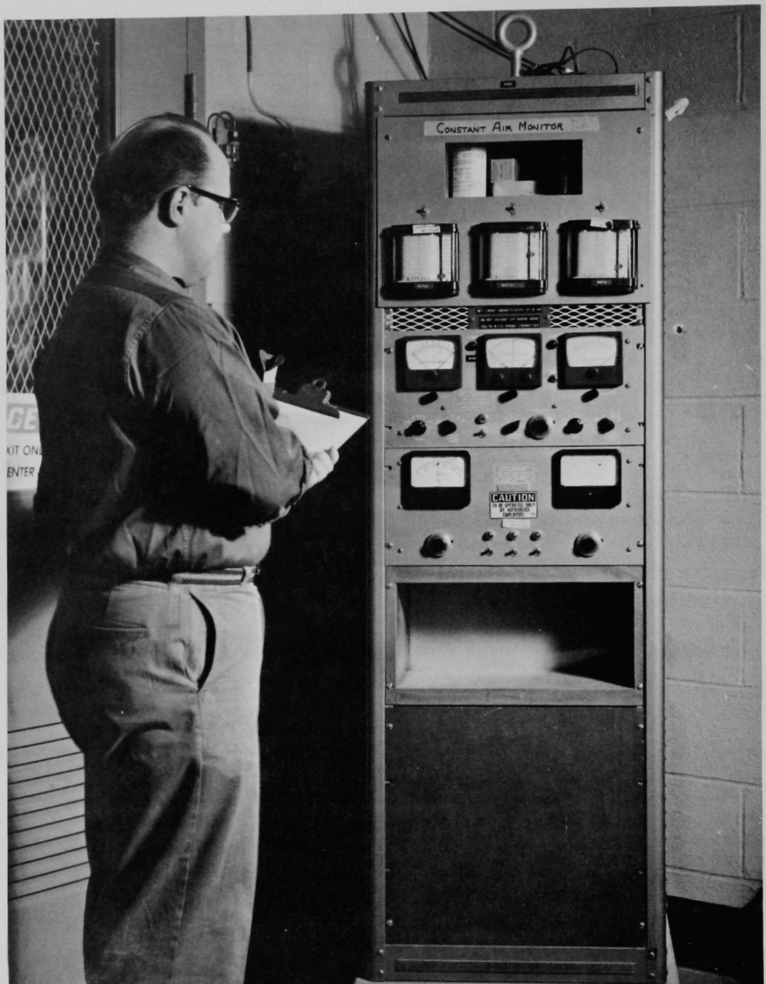

Fig. 21. Constant Air Monitor (CAM-5) Instrument Panel. (The CAM-5 is manufactured by the Tullamore Division of the Victoreen Instrument Co., Cleveland, Ohio.)

4.3.2 Glovebox Ventilation Control

The purpose of the ventilation alarm system is to warn personnel of the loss of vacuum in the gloveboxes while, at the same time, automatically activating certain corrective control devices. The alarms for the ventilation system are (1) an intermittent bell located at the main control panel and (2) indicator lights at the main control panel and in the corridor adjacent to the facility.

The following conditions will cause a ventilation alarm:

1. Low vacuum in either glovebox (above -0.3 in. H_2O).
2. Opening of the bypass damper (discussed below).
3. Loss of power to the booster blower (discussed below).
4. Large leak in the glovebox or an accidental breach.

The system is equipped with two automatic emergency controls. One control opens the bypass duct, which leads from the large glovebox directly to the ventilation-air scrubber, in the event of below-specification glovebox pressure. The process scrubber and the filter system directly downstream are thereby bypassed. If plugging of the process scrubber and filter system occurs, automatic opening of the bypass duct protects the large glovebox against overpressure. The bypass duct also provides additional ventilation of the large glovebox if the box develops a large leak.

The second automatic control is an independent pressure switch located at the discharge of the booster blower. The booster blower (discussed in Section 2.3.2) helps maintain negative pressure in the large glovebox and discharges essentially into the inlet plenum of the ventilation-air scrubber. If the pressure in the plenum rises above -0.7 in. H_2O, the pressure switch turns off the booster blower. Plenum pressure might increase if plugging occurs downstream from the ventilation-air scrubber. In this event, if the booster blower continued to operate, air flow in the main ventilation duct would be reversed, causing discharge of contaminated air from the large glovebox into the operating area. The booster-blower cutoff switch prevents that occurrence.

If the booster blower is stopped, pressure in the large glovebox increases, and the bypass duct opens automatically. The bypass duct remains open until it is manually reset.

Another safety feature of the bypass-duct system is an auxiliary air compressor that supplies air for actuating the bypass-duct damper if there is a loss of normal building ventilation air. Additional details on the emergency air supply system are given in Appendix O.

The acknowledge buttons for the glovebox ventilation alarms, the reset button for the bypass-duct damper, and the starter switch for the booster blower are located at the main control panel. The normal operating conditions for ventilation-system components are listed in Table IV.

4.3.3 Stack Air Monitor

The stack air monitor (components listed in Section 4 of Appendix K) detects alpha contamination in the ventilation air stream after it has passed through the ventilation scrubber and filtration systems just before discharge to the atmosphere. Activity is detected by passing a side stream of the main flow through filter paper mounted on an alpha-sensitive radiation probe. The alpha activity level on the filter paper is recorded on a continuous chart in the isolation room. If the activity level exceeds a preset value (indicating a buildup of alpha activity in the off-gas) or if the activity level drops below a preset value (indicating instrument failure), an alarm is sounded in the isolation room. Indicating lights are actuated at the control panel and in the corridor.

TABLE IV. Normal Operating Conditions for the Ventilation System

Process Scrubber	
Steam pressure	20 psig
Backwash pressure	0 psig
Pump pressure	35-42 psig
Flowrate	6 gal/min
Liquid level	4-10 in.
No. 1 filter ΔP	<0.75 in. H_2O
No. 2 filter ΔP	<0.75 in. H_2O
No. 3 filter ΔP	<1.0 in. H_2O
Inlet pressure (negative)	1.4-2.0 in. H_2O
Scrubber ΔP	<0.5 in. H_2O
Demister ΔP	<1.25 in. H_2O
Filter exit pressure (negative)	>4.0 in. H_2O
Enclosures	
Small-glovebox pressure (negative)	>0.4 in. H_2O
Large-glovebox pressure (negative)	>0.4 in. H_2O
Vacuum-pump-enclosure pressure (negative)	>0.4 in. H_2O
Ventilation-air Scrubber System	
Booster blower	On
Demister ΔP	<0.75 in. H_2O
Steam coil ΔP	<1.0 in. H_2O
AEC filters ΔP	<1.25 in. H_2O
Inlet plenum pressure (negative)	>1.35 in. H_2O
Total facility flow	<0.10 in. H_2O
Emergency bypass damper	Closed
Large-glovebox air flow	0.31-0.39 in. H_2O
Small-glovebox air flow	0.073-0.10 in. H_2O
Pump pressure	40 psig
Steam pressure	10 psig
No. 1 blower	On (principal)
No. 2 blower	Off
No. 3 blower	Off
No. 4 blower	On (emergency)

4.3.4 Fire-detection Alarm

The facility is equipped with an automatic fire alarm system* based on the heat-detection (temperature rate-of-rise) principle. Heat detectors shown in Fig. 22 are located as follows:

1. Along the entire length of the top and center of the large glovebox.
2. Along the ceiling of the cell.
3. Along the top of the small glovebox.
4. Along the ceiling of the isolation room.

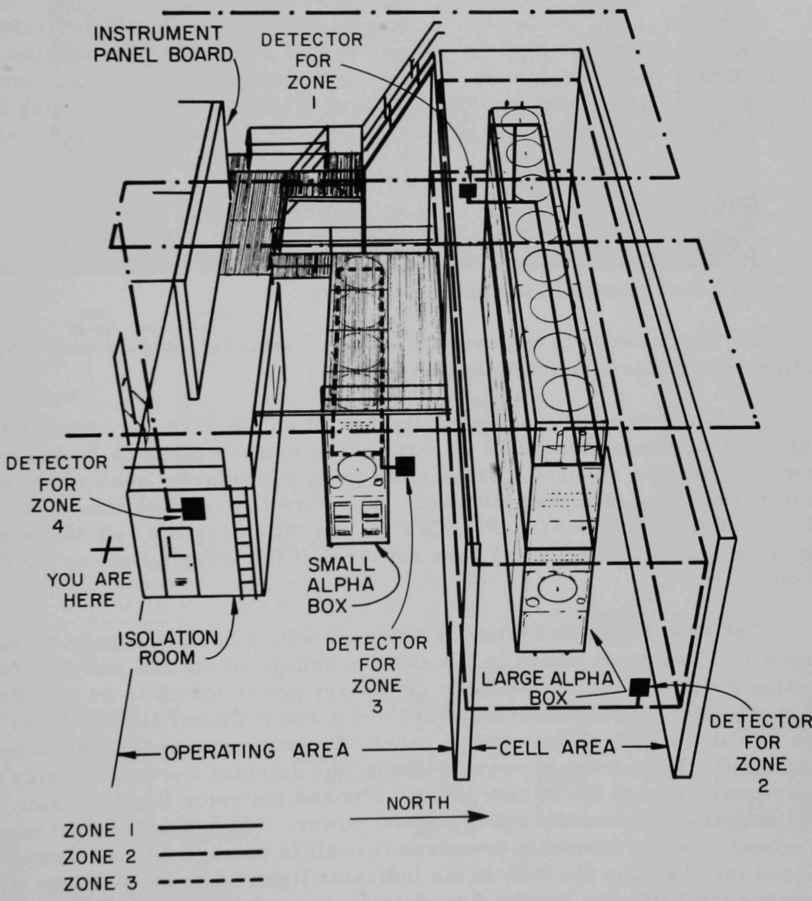

Fig. 22. Fire-detection System in the Alpha Facility

*Fire alarm system Model J-374-5, supplied by Walter Kidde Co., Belleville, New Jersey.

Even a low rate of temperature rise may cause an alarm. (Heating of insulated equipment too rapidly will set off the alarm.) The alarm is calibrated by applying a point heat source to the detector tubing. (The large alpha box system has about 120 ft of detector tubing.) During calibration the temperature at the heat source rises about 50°F/sec.

The fire-alarm control panel is located in the corridor just outside the facility. Items on the panel are detailed in Fig. 23. One alarm bell is located in the operations area; a second bell and a buzzer are located on the control panel.

The unit is set for automatic response (the green NIGHT indicator light is on) at all times. With the system in this AUTO-CALL condition, the Fire Department receives the alarm also and responds, unless otherwise directed (that is, unless a HOLD condition is instituted by phoning the Fire Department). Under normal conditions, all other indicator lights are off.

If the fire-alarm system is actuated, the following occurs:

1. A continuous bell and two buzzers sound at the fire-alarm control panel, and a bell sounds in the operations area.

2. The location of the detector that has been actuated is shown by a red light at the alarm control panel.

3. Simultaneously, a trouble light is lit on the Fire Department's panelboard, and unless the Fire Department is notified that this is a false alarm, the firemen respond. Other emergency procedures, such as evacuation of the building, are also initiated. (The Fire Department should be notified immediately if an alarm is a false alarm. Silencing the bell and buzzer at the fire-alarm control panel does not turn off the trouble light at the fire station.)

The fire-detection system is equipped with a battery supply, which automatically supplies power in the event of failure of normal power. The detection system operates normally on battery power for up to 24 hr. Power failure is indicated by an alarm buzzer and a red indicator light, both of which are at the fire-alarm control panel. The buzzer sounds when normal power is off. When normal power returns, the detector system remains on battery power though the buzzer stops. The red indicator light remains on until the system is transferred to normal power. The indicator light must be checked at short intervals to ensure that all is normal. A test switch is provided for checking the bulb in the indicator light. A trickle-charge system keeps the batteries for the fire-detection system charged. The batteries are equipped with indicators that show their charge at all times. The Fire Department regularly maintains this system.

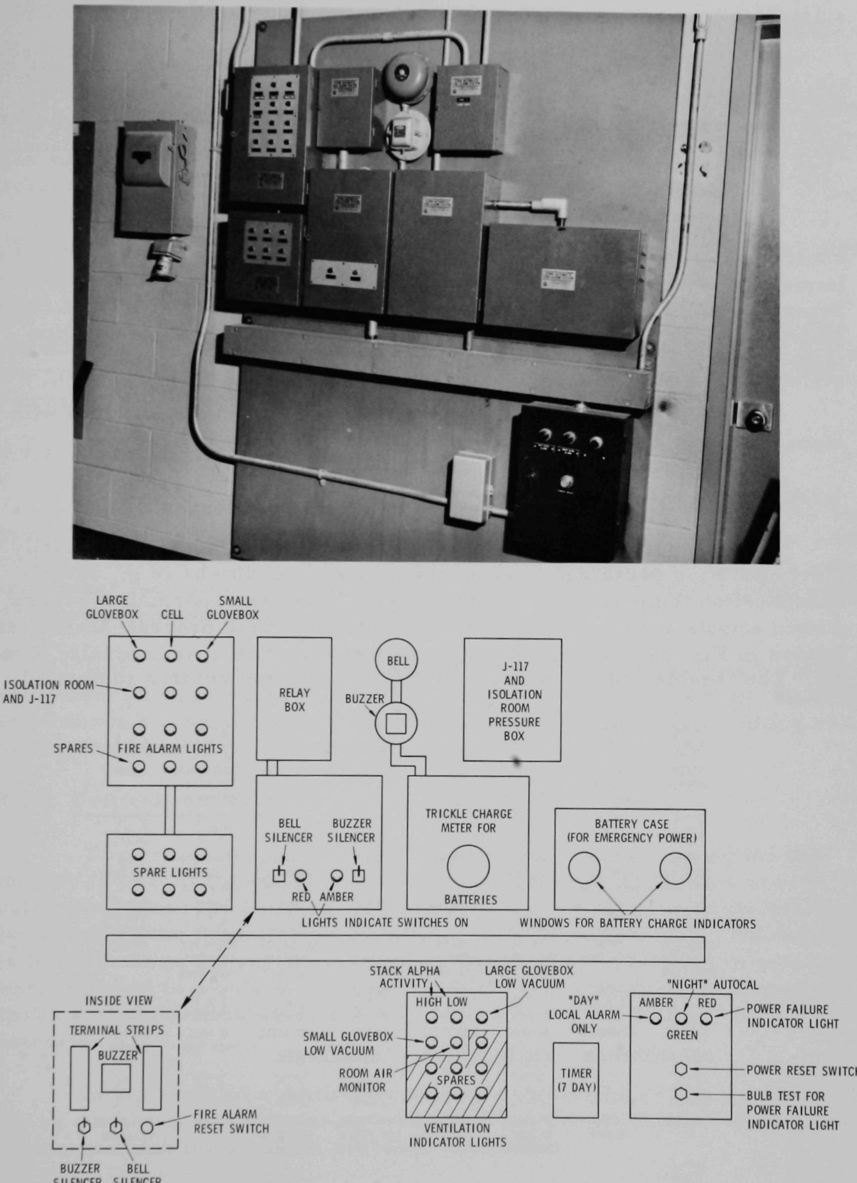

Fig. 23. Fire-alarm Control Panel. ANL Neg. No. 108-6720.

4.3.5 Personnel Hand and Foot Alpha Monitors

Alpha-radiation monitors are located at several locations near each glovebox, on each personnel lift, and at the entrance to the facility (isolation room). Contamination is most likely to be discovered by persons checking themselves upon entering or leaving the facility or when checking hands just removed from glovebox gloves.

Conscientious use of the monitors is essential for two reasons. First, the person is made aware whether he is contaminated and should take immediate action to protect himself and stop the spread of contamination. Second, personnel in the area are warned when there is a source of radioactive material open to the general atmosphere and appropriate action must be taken.

The procedure to follow in the event of an injury associated with alpha contamination is discussed in Section 4.4.5.

4.3.6 Process-abnormality Alarms

The process-alarm system for the facility is intended primarily to alert operating personnel to abnormal process conditions (e.g., out-of-specification temperatures or pressures). When an abnormality occurs, a horn sounds and an indicator light is actuated at the process-alarm panel (shown in Fig. 24). The horn continues to sound until it is manually turned off. The trouble light remains on until the condition returns to normal.

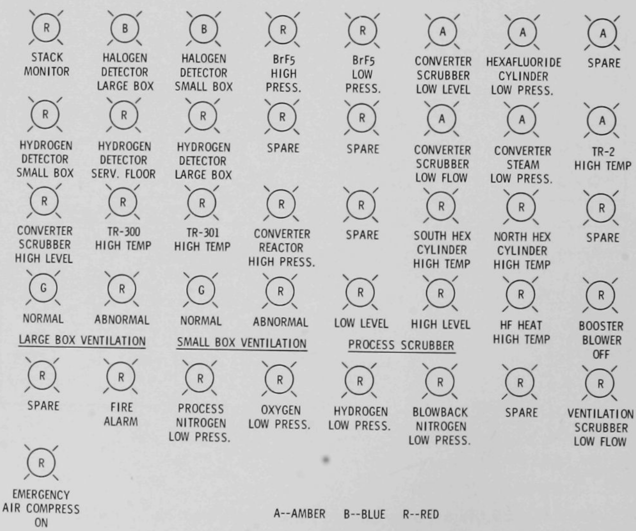

Fig. 24. Process-alarm Panel

The fire-detection alarm (Section 4.3.4), glovebox-ventilation alarm (Section 4.3.2), stack-air-monitor alarm (Section 4.3.3), and hydrogen-detection alarm (Section 4.3.10) have display lights at the process-alarm panel, but have separate alarm systems. The auxiliary air compressor has a trouble light, but no audible alarm. The nitrogen, oxygen, and hydrogen gas supply systems have duplicate lights (indicating low pressures) and acknowledge buttons located at the alarm panel and at the west wall of the work area in the operations room. Temperature recorders (e.g., TR-2, noted on Fig. 24) were wired to sound an alarm when a predesignated maximum temperature was reached.

All abnormalities indicated by process alarms are logged on data sheets provided at the control panel. During standby (nonoperating) periods, the process-alarm panel is periodically checked by the TOM for abnormal conditions.

4.3.7 Electrical-power-overload Alarm

The electrical power supply to the facility was not designed for the simultaneous use of all process equipment. When too heavy a load is placed on the electrical system (e.g., the transformer supplying the power), a warning buzzer indicates the overload. The buzzer and the alarm control panel are located behind the process control panel.

If the electrical-power overload buzzer sounds, enough electrical equipment should be turned off to correct the overload condition. When the condition has been corrected, the buzzer can be silenced by manually resetting the alarm at the control panel.

4.3.8 Criticality Alarm

The criticality-alarm system (described in Appendix L) for the facility is part of the building and site-wide system. Detectors are located throughout the building. The central control station for the building is located in the Radiation Safety office. The detector unit for the facility is located above the small glovebox on the cell wall. The unit is actuated when exposed to a beta-gamma field of 20 mR/hr or greater. At Argonne, a recording of the criticality alarm horn can be heard by dialing telephone extension 4761.

In the event of a criticality alarm, everyone must evacuate the building as quickly as possible using a route as far removed as possible from the region in which the accident probably occurred.

4.3.9 Building-evacuation Alarm

Anyone discovering an emergency condition should take immediate action to protect personnel and property. Argonne National Laboratory has established an emergency control center to provide assistance in such situations. The center can be contacted by dialing 13 on any telephone at the laboratory. Dialing this number connects the caller with an emergency operator who, in turn, notifies the Fire Department, the Radiation Safety control office, the Plant Security control office, and the Health Division, as required by the emergency. The operator also contacts the Chemical Engineering Division safety officer, who can give instructions or order a building evacuation via the building public-address system.

Located throughout the building are manually operated sirens to be used if rapid building evacuation is necessary.

Persons using the "dial 13" system (or operating the building-evacuation sirens) must provide sufficient information to the emergency operator (or the building fire brigade) to permit effective response to the emergency. The person calling the emergency operator must give his name, the extension phone being used, information concerning the nature of the emergency, and a concise location of the emergency. When the building-evacuation siren is used, extension 13 should be called as soon as possible after the alarm is given.

4.3.10 Hydrogen-detector Alarm

The hydrogen supply manifold is located outside the west wall of the building. Hydrogen is brought in through a double-wall pipe, with the annulus vented just upstream of the ventilation scrubber.

The hydrogen detector is described in Appendix H. Hydrogen-detector heads are located (1) in the large glovebox above the converter, (2) in the small glovebox above the converter off-gas scrubber, and (3) at the west wall of the operations room, connected to the annulus of the hydrogen feed line.

The function of the hydrogen-detection system is to alert personnel to accumulation of hydrogen. The detectors are set to activate the alarm at a hydrogen concentration of 1% (4.1% is the lower explosive limit in air). The system is operative only when hydrogen is being used in the process. Actions to be taken in response to the alarm are summarized in Table III.

4.4 Emergencies with No Accompanying Automatic Audible Alarm

In some instances, accidental releases of radioactive or chemically hazardous material or some other emergency-type situation may occur without the sounding of an automatic audible alarm; it is anticipated that operating personnel will be aware of such emergencies, which may occur inside a glovebox or in the room proper.

4.4.1 Release of Radioactive or Chemically Hazardous Material in the Glovebox

If volatile plutonium compounds, fluorine, or other hazardous materials are accidentally released inside a glovebox, the most important consideration is maintaining the integrity of the glovebox. Instrumentation must be checked to make sure that the ventilation system is operating properly and is effectively removing activity from the air stream before it is discharged to the stack, and that the proper negative pressure is being maintained in the gloveboxes. When fluorine or interhalogens are released, an additional danger is that activity can be released as a result of filter or glove damage.

The following action is recommended in the event of a release inside a glovebox:

1. Phone Radiation Safety. Check instrumentation to make sure that the gloveboxes are under proper vacuum, that the ventilation and process scrubbers are operating satisfactorily, and that the reading of the stack air monitor is within permissible limits. Continue to monitor these instruments.

2. Prepare for the possibility that containment might be lost. Don protective clothing and respirator equipment. Shut down the process equipment.

3. If possible, remotely or manually shut off leaking equipment. Move gloves and other combustible material away from the direction of the leak.

4. If there appears to be danger of either a loss of containment or release of radioactive material to the stack, dial 13 for assistance.

4.4.2 Release of Radioactive or Chemically Hazardous Material in the Operating Area

A useful summary of steps to take after a release of radioactive material in the general room area is provided by the following excerpt from a review by Steindler:[2]

1. Warn other occupants of the room; hold your breath; leave the room. Remember that your primary responsibility is the safety of yourself and others. Possible loss of materials is entirely secondary. If you have time, while you hold your breath, you may do a few things to prevent the spread of contamination: right any tipped containers, drop absorbent pads on liquids. If you hold your breath, you will not inhale radioactive particles that may be in the air.

2. Close the door and ask someone to prevent entry until a proper hazard sign is posted. The room may be entered only with the knowledge of a Radiation Safety representative.

3. Wash and flush any radioactive material from your skin. Use the emergency shower if necessary.

4. While you are still washing, ask someone to dial 13 and give the details and location of the accident; the emergency operator will notify Radiation Safety.

5. Remove contaminated clothing, and place it in an active-waste container.

6. Check your body for cuts and abrasions. If there are any, whether or not they were caused by the accident, obtain medical assistance.

7. Be certain that your supervisor is notified of the incident.

8. Alert personnel in adjoining areas.

9. If no immediate medical attention is needed, wait for the Radiation Safety representative.

All cleaning operations are to be done with the approval of the Radiation Safety Section.

If fluorine, HF, or interhalogens are released into a room or building, the primary concern is prevention of injury through inhalation or burns. Both the vapor and liquid forms of these materials cause severe burns to any exposed part of the body. Therefore, wearing of both respiratory protection and protective clothing is necessary. Types of personal respiratory protective equipment available for use in the facility include: assault masks (air-purifying respirators)--one for each person; Scott Air Pak* (self-contained breathing apparatus)--three sets; air-supplied respirator--two sets. Instruction in the use of this equipment is a normal part of the operator's training. Where high concentrations of these materials are involved, protective clothing is of little use.

If leaks occur when operating personnel are not standing by with protective clothing, or if a leak cannot be controlled immediately, the following actions are recommended:

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*A product of the Scott Aviation Corporation, Safety Equipment Division, Lancaster, New York.

1. Warn others in the facility, and evacuate to a safe place while holding breath.

2. Dial extension 13 or use the siren so that occupants will evacuate the building. Direct people away from the area involved.

3. Notify Radiation Safety and supervisory personnel.

4. Be sure that personnel equipped with maximum protective equipment use caution when entering the area. If possible, they should take corrective action to minimize the effect of the leakage and to shut down process equipment if a process run is in progress.

4.4.3 Fires inside the Glovebox

Possibly the greatest hazard in the facility is the loss of containment as a result of fire damage to the gloveboxes or plugging of the outlet filters by smoke. Operating personnel will usually be aware of a glovebox fire before it is detected by the heat-sensitive fire alarm. Though operating personnel should attempt to extinguish small fires, the Fire Department must be notified ("dial 13" procedure) immediately upon discovery of a fire. The following actions are recommended in the event of a fire in one of the gloveboxes:

1. Dial 13 and give the operator the necessary information.

2. Attempt to extinguish small fires with the fire extinguishers provided in the facility. At least two people wearing positive-pressure respirators are required. (Three types of fire extinguishers available are described in Appendix M.)

3. Shut down process equipment, and turn off electrical power to the area involved as soon as possible.

4.4.4 Fires outside the Glovebox

Though the risk of radioactive release is somewhat less for fires outside the gloveboxes than for those inside the gloveboxes, the radioactivity hazard should not be overlooked. A fire involving the entire facility would necessarily include the gloveboxes. Here again, speed of action is vital. In general, the action taken for a fire outside the glovebox is identical to the procedure outlined above for in-glovebox fires.

4.4.5 Injury to Personnel

As a safety precaution, at least two operating personnel must be present in the facility when glovebox work or hazardous operations are being performed. In the event of a serious injury, any available person should dial 13 for assistance. In general, the injured person should not be moved (unless his position places him in imminent danger). Severe bleeding can be stopped with a compress available in any safety cabinet. If the injured person is not breathing, artificial respiration should be administered.

If fluorine, HF, or interhalogen burns have occurred, this material must be washed off with water immediately (see Sections 6 and 7 of Appendix E). If reagents are inhaled in large quantities and breathing difficulties result, oxygen gas should be administered, using the oxygen cylinder in the safety equipment supplies.

If bodily injury is incurred along with a contamination incident, there are obvious complications that will affect the standard procedure. In general, all personnel must be warned of the contamination so that they may evacuate the facility. Wearing assault masks, personnel must return to the victim, place an assault mask on him, and move him to the place of greatest safety without significantly spreading contamination. A "dial 13" call must be made to obtain medical and Radiation Safety assistance. Feasible first aid can now be administered to the victim (keep open wounds covered to exclude radioactive contaminants). Medical and Radiation Safety personnel will take charge of the incident on arrival.

4.4.6 Electric Power Failure

A general power failure will be accompanied, almost simultaneously, by a transfer to emergency power (developed by a diesel-driven generator housed in the building). Emergency power will maintain in operation all systems that are critical to the facility, as described in Appendix N. Personnel need only silence various alarms caused by the failure and shut down any process run in progress. Restoration of normal power requires no further operations other than transferring the heat-detection alarm system from battery power to normal power.

APPENDIX A

Hazards of Handling Plutonium

The principal hazards associated with plutonium are its toxicity and criticality. The expected neutron levels are not a major concern, nor is beta-gamma radiation of much concern if the plutonium is free of fission-product contaminants.

1. Alpha Radiation

The human body has an extremely low tolerance for plutonium. The reasons for this low tolerance are that plutonium (1) is an alpha emitter, (2) tends to become fixed within the body, and (3) has a long effective half-life (200 yr). (Effective half-life is the time required for one-half the material to be discharged from the body by elimination and decay of the isotope.)

The predominant radiation from ^{239}Pu (see Table V) consists of alpha particles with energies of 5.10, 5.13, or 5.15 MeV. Alpha particles

TABLE V. Physical Constants for the Long-lived Isotopes of Plutonium[10]

Isotope	Mass	Half-life, yr	Decay Mode[a]	Decay Energy, MeV	Particle Energy, MeV	Particle Intensity, %	Gamma Energies, MeV	Gamma Intensity, %	Thermal-neutron Cross Section,[b] barns
^{236}Pu	236.0461	2.85	α	-	5.763	69	0.046	0.047	σ_f 270
				-	5.716	31	0.110	0.012	-
				-	5.610	0.18	0.165	6.6×10^{-4}	-
^{238}Pu	238.0495	89	α	-	5.491	72	0.0436	0.038	σ 400
				-	5.448	28	0.0996	8×10^{-3}	σ_f 17
				-	-	-	0.152	1×10^{-3}	-
				-	-	-	0.203	4×10^{-6}	-
				-	-	-	0.760	25×10^{-5}	-
				-	-	-	0.810	$\approx 2 \times 10^{-5}$	-
				-	-	-	0.875	-	-
^{239}Pu	239.0522	24,360	α	-	5.147	72	0.003	-	σ 270
				-	5.134	17	0.0125	-	σ_f 740
				-	5.096	11	0.038	-	-
				-	-	-	0.052	360	-
				-	-	-	0.121	70	-
				-	-	-	0.207	20 (relative)	-
				-	-	-	0.340	30	-
				-	-	-	0.3800	60	-
				-	-	-	0.420	40	-
^{240}Pu	240.0540	6.58×10^3	α	-	5.159	76	0.042	24	σ 290
				-	5.114	24	0.047	-	-
				-	5.01	0.1	-	-	-
^{241}Pu	-	13	β^-	0.021	0.02	99	0.100	100	σ 400
			α	-	4.893	-	0.145	20 (relative)	σ_f 1000
				-	4.848	-	-	-	-
^{242}Pu	242.0587	3.79×10^5	α	-	4.898	76	0.045	24	σ 23
				-	4.854	24	-	-	-
^{244}Pu	-	7.6×10^7	α	-	-	-	-	-	-
				-	-	-	-	-	-

[a]All the plutonium isotopes listed except ^{241}Pu also decay by spontaneous fission (SF).
[b]σ_f = fission cross section, σ = thermal-neutron capture cross section.

with these energies have a range of about 3.7 cm in air and 40 μm in soft tissue. Since the skin has a thickness of 40-150 μm, the alpha particles do not present a hazard if they are outside the body. However, the high specific alpha activity of plutonium makes it extremely deleterious when inside the body.

Plutonium may enter the body by inhalation, ingestion, injection, or absorption through the skin. Upon entering the circulatory system, the element "seeks" certain areas of the body and becomes fixed there.[11] These areas, in descending order of "takeup," are bone marrow, bone cortex, periosteum, liver, spleen, lung, kidney, reproductive organs, heart, and intestines.

The maximum permissible body burden for soluble ^{239}Pu is 0.65 μg. The permissible body burdens for insoluble ^{239}Pu, ^{238}Pu, ^{240}Pu, ^{241}Pu, and ^{242}Pu are considerably smaller (see Table VI). The safe burden limit can be reached by repeated exposure (cumulative effect) as well as by consequence of a single incident.

TABLE VI. Permissible Body Burdens for Plutonium Isotopes[2]

Plutonium Isotope	Water,[a] μg/ml	Air,[b] μg/ml	Maximum Body Level,[c] μg
238	8.7×10^{-8}	1.1×10^{-13}	4.6×10^{-4}
239	2.4×10^{-5}	3.2×10^{-11}	0.13
240	6.7×10^{-6}	9×10^{-12}	3.6×10^{-2}
241	1.3×10^{-8}	1.7×10^{-14}	7×10^{-5}
242	3.8×10^{-4}	5.1×10^{-10}	2

[a]Based on 1.5×10^{-6} μCi/ml for continuous exposure.
[b]Based on 2×10^{-12} μCi/ml for continuous exposure; the corresponding value for uranium is $\sim 5 \times 10^{-5}$ μg/ml.
[c]Based on insoluble plutonium, 8×10^{-3} μCi; soluble plutonium limit is 4×10^{-2} μCi.

2. Beta-Gamma Radiation

A small percentage of the radiation from ^{239}Pu and ^{240}Pu is emitted as weak gamma and X rays (see Table V). Plutonium-241 decays primarily with beta emission, but alpha and gamma radiation are also emitted in a small percentage of the disintegrations. Additional gamma radiation comes from daughter products such as americium-241 (produced by beta decay of ^{241}Pu). Beta-gamma radiation, along with neutrons, constitutes the external radiation exposure hazard from plutonium and associated products.

3. Neutron Radiation

The neutron flux associated with plutonium in the fluoride-volatility process comes from two nuclear phenomena (see Table VII). Spontaneous fission of the plutonium atom with accompanying emission of neutrons is one phenomenon. Of more importance to the process, however, is the α,n reaction. In this reaction, neutrons are produced when the nuclei of light elements (fluorine in particular) interact with alpha particles. The neutron flux produced by the $^{19}F(\alpha,n)^{22}Na$ reaction is considerably higher than that produced by spontaneous fission.

TABLE VII. Neutron-emission Parameters for Plutonium[13]

Plutonium Isotope	n/(sec) (g plutonium)		
	Spontaneous Fission	PuF_4 α,n	PuO_2 α,n
238	3.4×10^3	2.1×10^6	1.4×10^4
239	0.02	4.2×10^3	45
240	1×10^3	1.6×10^4	170
241	Very low	Very low	Very low
242	1.7×10^3	1.7×10^2	2.7

Experimental data on the neutron flux from samples of plutonium fluorides (or plutonium metal) are not generally available. Helgeson[12] has indicated that a 450-g sample of PuF_4 contained in a 1/4-in.-wall Plexiglas container has a surface dose rate of 3.0 Rem/hr fast neutrons and 1.5 Rem/hr gamma and X ray. The average energy of the neutrons is stated to be 0.75 MeV. Although no primary data are given in this report, a surface dose rate of 3.0 Rem/hr of 0.75-MeV neutrons is approximately equivalent to a specific neutron-emission rate of 5300 n/(sec) (g Pu).

4. Criticality

When a sufficient amount of fissionable material, such as plutonium or uranium, is assembled in a shape such that more neutrons are produced than escape from the surface, criticality is reached. The emanating neutron flux increases rapidly, and intense radiation is produced. This condition continues until a physical or chemical change occurs that makes the system subcritical. Since the level of radiation from an unshielded critical assembly greatly exceeds all tolerated levels, the only action that should be taken in case of criticality is to evacuate the area immediately.

The minimum critical mass of ^{239}Pu under optimum moderation and reflection is 510 g (see Table VIII). The quantity of natural or depleted uranium required for a critical mass is so large and the conditions required are so stringent that little possibility of criticality exists for uranium.

TABLE VIII. Nuclear Parameters for Plutonium-239[14]

	Recommended Value	Minimum Critical Mass
Mass, kg		
In solution	0.22	0.51
Metal	2.6	5.6 alpha phase
	3.5	7.6 delta phase
Diameter of cylinder of infinite length, in.		
Solution	4.2	4.9
Metal	1.4	1.7 alpha phase
	1.8	2.1 delta phase
Thickness of slab of infinite length, in.		
Solution	0.9	1.3
Metal	0.18	0.24 alpha phase
	0.22	0.28 delta phase
Solution volume, liters	3.4	4.5
Chemical concentration of aqueous solution, g (of isotope)/liter	6.9	7.8

NOTE: Each value given is to be considered by itself and bears no relationship to other values in the table.

In general, the conditions that most favor a criticality incident are as follows:

1. The fissionable material is free of neutron-absorbing materials.

2. The fissionable material is dispersed in a neutron-moderating material such as water.

3. The fissionable material is in a shape (such as a sphere) that has a low surface-to-volume ratio.

Plutonium compounds that do not contain moderating materials have a larger critical mass than the 510-g minimum value. The values for critical mass differ from compound to compound (see Table IX).

TABLE IX. Critical Mass and Radii for Plutonium Compounds[14]

			Infinite Cylinder		Infinite Slab	
	Minimum Critical Mass,[a] kg	Safe Mass, kg	Critical Radius, in.	Recommended Safe Radius, in.	Critical Thickness, in.	Recommended Safe Thickness, in.
^{239}Pu metal	5.6	2.6	0.85	0.7	0.24	0.18
PuO_2	13.0[b]	5.6	2.36	1.96	-	-
PuF_4	-	6.0[c]	3.58[d]	2.98	-	-
PuF_6	-	-	4.78[d]	3.98	-	-
^{239}Pu in solution	0.51	0.22	2.45	2.1	1.3	0.9

[a]Natural water reflection of effectively infinite thickness is assumed.
[b]For ^{239}Pu and a density range of 5-10 g/cc.
[c]Based on an allowance factor on mass limits given in Nuclear Guide (TID-7016, Rev. 1, 1961), Fig. 19, p. 23.
[d]Five-inch-thick iron reflector. This is a calculated value.[15]

APPENDIX B

Physical Characteristics and Properties of Uranium and Its Compounds[10]

Name	Formula	Molecular Weight	Density or Specific Gravity	Melting Point, °C	Boiling Point, °C
Uranium	U	238.03	19.05 ± 0.02	1123.3 ± 0.8	3818
Dicarbide	UC_2	262.05	11.28 (16°C)	2350-2400	4370 (760 mm)
Chloride, penta-	UCl_5	415.30	3.81	Decomposes at 300	-
Chloride, tetra-	UCl_4	379.84	4.87	590 ± 1	792 (760 mm)
Chloride, tri-	UCl_3	344.39	5.44 (25°C)	842 ± 5	-
Fluoride, hexa-	UF_6	352.02	4.68 (21°C)	64.5-64.8	56.2 (765 mm)
Fluoride, tetra-	UF_4	314.02	6.70 ± 0.10	960 ± 5	-
Fluoride, tri-	UF_3	295.03	-	Decomposes at 1000	-
Oxide, di-	UO_2	270.03	10.96	2500	-
Tri-oxide, oct-	U_3O_8	842.09	8.30	Decomposes at 1300 to UO_2	-

APPENDIX C

Excerpts from the ANL Radiation Safety Guide[6]

1. Working at Night and on Holidays

Radiation Safety must be notified if, at any time other than normal working hours, you intend to work with radioactive materials whose activity exceeds 10^6 dpm. Additionally, you must secure the approval of the Director of your Division if you plan to work alone.

2. Active Areas

An active area is an area in which radioactive materials are located in such amounts that they constitute a potential personnel hazard or increase the possibility for spread of contamination. Occupants of active areas are responsible for having such areas clearly defined and marked.

Certain regions of the Laboratory have been specifically delineated as areas where radiation hazards normally exist. These locations have been distinctly designated and marked as such by the authority of the responsible Division Director.

Every individual entering an active area is required to wear personnel monitoring devices, which are found at the entrance to the area. In some areas, toe rubbers, safety glasses, and other types of protective equipment must be worn. Read the instructions posted at the entrances to the area, and be guided accordingly.

3. Eating and Smoking Regulations

Eating, storing, or preparing food in areas where radioactive materials are handled is prohibited. Protective clothing or devices used in connection with radioactive work shall not be taken into any area where food is stored, prepared, dispensed, or eaten.

Do not smoke in an active area unless specific permission is granted by the supervisor in charge of the area.

4. Wearing of Personnel Monitoring Devices

The Laboratory provides film badges and self-reading dosimeters to all individuals required to work in the vicinity of radioactive materials. These must be worn whenever there exists a possibility of exposure to radiation; they are considered part of normal laboratory equipment. All such devices are to be picked up each morning upon entering and returned to the appropriate depository upon leaving the building.

Dosimeters and film badges must not be tampered with in any way. If you have a discharged dosimeter or one that is suspected of not being in proper working condition, report it immediately to Radiation Safety

TABLE X. Radiation Units

Unit	Description
Roentgen (R)	The quantity of X or gamma radiation such that the associated corpuscular emission will produce one esu of charge (corresponding to 2.08×10^9 ion pairs) of either sign in 1 cc of air at standard conditions. This indicates the absorption of 83 ergs per gram of air.
Milliroentgen (mR)	1/1000 of a roentgen; that is, 1 mR = 0.001 R.
Roentgen equivalent physical (Rep)	The quantity of ionizing radiation that will result in the absorption in tissue of 93 ergs per gram.
Roentgen equivalent man (Rem)	The quantity of radiation which, when absorbed in tissue, produces a biological effect equivalent to the absorption by man of 1 R of X or gamma rays.
Curie (Ci)	The quantity of any radioactive substance in which the number of disintegrating atoms is 3.7×10^{10} per sec.
M	Used to indicate alpha contamination and designates thousands of disintegrations per minute per 100 cm^2 of probe coverage.
Relative Biologic effectiveness (RBE)	The ratio of X or gamma-ray dose to the dose required to produce the same biological effect by the radiation in question.
rad	The quantity of radiation that will result in the absorption in any medium of 100 ergs per gram.

NOTE: Where abbreviations adopted by the Chemical Engineering Division differ from those in the Radiation Safety Guide, the former are used.

TABLE XI. Maximum Permissible Exposures for External Radiation

(Total body exposures)

Type	Dose
X rays and gamma rays	300 mR/week
Beta rays	500 mRep/week
Beta and gamma rays (sum)	500 mRep/week
X rays (below 15-kV average)	500 mR/week

TABLE XII. Maximum Permissible Neutron-flux Densities

Energy, MeV	Neutron-flux Density, n/(cm^2)(sec)	Energy, MeV	Neutron-flux Density, n/(cm^2)(sec)
10	30	0.5	80
5	30	0.1	200
4	30	0.01	1000
3	30	10^{-5}	1000
2	40	2.5×10^{-8} (thermal)	2000
1	60		

APPENDIX D

Physical Properties of Fluorine and Gaseous Fluorides[10]

Name	Formula	Molecular Weight	Density or Specific Gravity	Melting Point, °C	Boiling Point, °C
Fluorine	F_2	38.00	1.69 (15°C)	-219.62 (760 mm)	-188.14 (760 mm)
Chlorine mono-	ClF	54.45	1.51 (-188°C)	-154-5	-100.8
Chlorine tri-	ClF_3	92.45	1.77 (13°C)	-83	11.3
Bromine mono-	BrF	98.91	-	Decomposes at -33	-20
Bromine penta-	BrF_5	174.90	2.466 (25°C)	-61.3	40.5
Bromine tri-	BrF_3	136.90	2.49 (135°C)	8.8	135
Hydrogen fluoride	HF	20.01	0.99 (19.54°C) liq 0.987	-83.1	19.54

APPENDIX E

Safety Data for Bromine Trifluoride and Bromine Pentafluoride

(Excerpts from a memorandum prepared by O. J. DuTemple, 1951; revised by W. J. Mecham, 1958, and by M. J. Steindler, 1966)

1. Names and Formulas

Bromine trifluoride	BrF_3
Bromine pentafluoride	BrF_5

2. Composition and Purity

Commercial grade:	98% BrF_3 or BrF_5, as stated by Matheson Chemical Co. Contamination of BrF_5 or BrF_3 is from lower fluorides (BrF_3 in BrF_5) and bromine. May contain some HF, air, etc.
Laboratory purified:	Purity depends on extent of purification. Can be better than 99% pure.

3. Physical Properties

	BrF_3	BrF_5
Vapor pressure (20°C)	5.5 mm Hg	330.6 mm Hg
Density (liquid) 10°C	2.839 g/cc	2.516 g/cc
60°C	2.700 g/cc	2.343 g/cc
Color (liquid)	Light straw yellow (colorless-yellow gray)	Pale yellow
Odor	Pungent, irritating	Pungent, irritating
Critical temperature	About 327°C	About 197°C

4. Chemical Reactivity

Both interhalogens can react explosively with water and organic materials at ambient temperatures. Both interhalogens are very reactive, converting most halides to the highest valence of the element. The interhalogens etch glass and quartz; they ignite paper, wood, paint, grease, and many plastics; reaction with organic chemicals is usually violent; both interhalogens fume extensively in moist air. Accepted materials of construction are similar to those used for fluorine service. Mild steel appears to be acceptable for use with interhalogens up to 200°C.

5. Fire Hazard

Neither interhalogen is flammable by itself. However, the large amount of heat evolved in the reaction between the interhalogens and materials such as wood, paper, most organic materials, finely divided metals (chips, filings), etc. is sufficient to ignite these materials, causing a fire hazard. On contact with wood and inorganic materials such as concrete, the interhalogens react with explosive violence and spatter. Each spattered droplet then again reacts on contact with these materials, causing additional spattering. In the event of a spill of appreciable size onto the floor, a series of bouncing drops scatter over the floor and continue to react until all the fluorinating agent is exhausted. These events are accompanied by sharp explosions and occasionally by fire, depending on the surroundings.

6. Health Hazard

Both interhalogens are extremely hazardous chemicals, causing both chemical and thermal burns on contact with any parts of the body. The reactions of the interhalogens produce HF and generate a large amount of heat. Contact of liquid interhalogens with the eye causes total destruction of the eye. Contact of the vapors with the eye causes severe irritation, which may lead to partial destruction of portions of the eye. Inhalation of interhalogen vapor is extremely irritating to the respiratory tract. Sore throats, headaches, and inflammation and/or congestion of the lungs are observed after inhalation of low concentrations of the vapors. Inhalation of large concentrations of interhalogens results in asphyxiation due to spasm of the larynx. The maximum allowable concentration of interhalogen vapor in air is 1 ppm for an 8-hr day. It is reported that 1 ppm of ClF_3 is detectable by odor, but this type of data is not available for BrF_3 or BrF_5. By analogy with ClF_3, 50 ppm interhalogen vapor in the air may be fatal in 30 min to 2 hr. When swallowed, interhalogens immediately cause severe irritation of, and damage to, the esophagus and the stomach. Severe irritation of the respiratory tract also occurs, and death is probable. Chronic toxicity of interhalogens has not been recorded.

7. First Aid

Speed is essential in the treatment of interhalogen burns. All exposures to interhalogens should be treated rapidly, in a manner similar to that used for a combination of thermal and HF burns. First aid should be started immediately after removal of the injured from the area of continuing exposure. Workers who have been exposed to interhalogens should be immediately subjected to a drenching shower of water. The clothing should be removed as rapidly as possible, while showering is in progress. Medical assistance (by dialing extension 13) should be obtained immediately.

Prolonged washing of the affected area and/or the whole body with water is essential so that all the hydrofluoric acid is removed from the skin. After washing with water, apply a saturated solution of magnesium sulfate (Epsom salts) or iced 70% alcohol for at least 15 min. Lime water is also useful, as is 5% sodium carbonate or a mixture of 20% magnesium sulfate, 6% magnesium oxide, 18% glycerol, 1.2% procaine chloride, and water. If the affected area is such that immersion in magnesium sulfate or alcohol is impractical, then iced alcohol or magnesium sulfate should be applied with compresses that should be changed every 2 min; this treatment should be continued for 30 min. This treatment is similar to that used for HF burns.

If interhalogen has entered the eye or if the eyes have been exposed to interhalogen vapors, the eyes should be irrigated immediately with copious quantities of water for at least 15 min. The eyelids should be held open during irrigation to ensure thorough contact of water with all affected tissue. Medical attention should be requested immediately.

A worker who has been overcome by gaseous interhalogen must be carried to an uncontaminated area. The assistance of a physician should be obtained immediately, and, if possible, oxygen or artificial respiration should be administered. To prevent the development of severe lung congestion (pulmonary edema), 100% oxygen should be administered as soon as possible after exposure.

8. Suggestions for Medical Treatment

Interhalogen burns always leave evidence of a thermal burn; evidence of an acid burn (HF) may not appear for several hours.

Whenever there is a possibility of an acid burn, calcium gluconate solution (1 g of calcium gluconate to 10 cc water) should be injected by infiltrating the skin and subcutaneous tissue in the same manner as is used in the injection of a local anesthetic subcutaneously. All skin that has been exposed to the acid should be infiltrated, including at least 1/4 to 1/2 in. around the exposed area. This treatment usually prevents the development of severe burns since the fluoride ion reacts with the calcium to form inert calcium fluoride.

9. Personal Protective Procedures and Equipment

Depending on the circumstances, the following protective equipment should be available to all personnel working with interhalogen compounds:

Leather gauntlet gloves

Leather jacket

Plastic face shield

Assault mask with gray (M-11) cannister

Leather trousers

Hard-shelled safety helmet (hard hat)

Respirator equipment using externally supplied air (Scott Air Pak, etc.).

In addition to these, all personnel must at all times wear:

Safety glasses

Safety shoes (leather).

Workers must never expose the skin to interhalogen vapors; hence, sleeves must be rolled down and/or laboratory coats must be worn. Whenever possible, safety glass of hoods or other enclosures should be placed between the source of interhalogen and the workers. If work with interhalogens is being done in vacuum-frame hoods with access to the interior from two sides, suitable attention should be given to personnel working in the hood at other locations. Visitors to the laboratories must observe the normal precautions of wearing safety glasses and, if circumstances indicate, must wear face shields and other protective equipment if operations with interhalogens are to be viewed.

None of the equipment listed above will completely resist the action of interhalogen liquids but will slow the reaction sufficiently to permit personnel to take evasive action (remove hands from gloves, leave the room, shower, etc.). Leather gloves used for miscellaneous tasks are generally somewhat greasy and should not be used for interhalogen work. Rather, sets of leather gloves should be reserved for interhalogen work. Face shields (available from stock) should be worn, together with leather gloves, for all work with interhalogens. Although it may not be necessary to wear an assault mask when certain operations are being carried out, an assault mask should be readily available to the worker, and each worker must be familiar with all techniques for rapidly and efficiently using such a mask. Protective clothing should be located conveniently, and each worker likely to work near interhalogens should have a full complement of equipment assigned to him.

First-aid supplies to be kept on hand include saturated magnesium sulfate solution, 5% sodium carbonate solution, sterile towels for compresses, magnesium oxide-glycerol paste, 70% alcohol solution, oxygen, blankets, a working eye-wash fountain, and safety showers.

APPENDIX F

Precautions in Handling and Storing Fluorine[4]

Although fluorine is the most reactive element and recognized as a very dangerous material, it can be handled without undue hazards if proper precautions are taken. To minimize the risks involved, observe the following measures:

1. In handling fluorine under pressure, use remote-controlled valves, preferably those operated by manually actuated extension handles passing through a suitable barricade.

2. Near the source of high-pressure fluorine use regulators or double valving to facilitate a safe reduction of pressure. Also use regulators or double valving where large quantities of fluorine are being handled, such as with manifolded cylinders, to minimize control failures.

3. Before using any equipment for fluorine service, be sure it is first thoroughly cleaned, degreased, and dried, then treated with increasing concentrations of fluorine gas so that any impurities may be burned out without the simultaneous ignition of the equipment.

4. Wear clean neoprene gloves when directly handling equipment that contains fluorine or that has recently contained fluorine. This precaution not only affords protection against fluorine but also against films of hydrofluoric acid, which may be formed by escaping fluorine reacting with moisture in the air and which may coat externally exposed parts. Wear neoprene coats and boots to afford overall body protection for short intervals of contact with low-pressure fluorine. All such protective clothing should be designed and used, however, so that it can be shed easily and quickly.

5. Wear safety glasses at all times. Metal frames rather than the customary plastic are desirable to eliminate the possibility of the frames catching fire.

6. Avoid repeated bending or excessive vibration of piping or equipment. Such mechanical actions can result in a flaking of the protective fluoride film, resulting in a rupture of the metal with or without the occurence of a fluorine-metal flame. Flaking, furthermore, can be accompanied by dusting with the resultant fouling of valves.

7. If any equipment has contained fluorine, be sure it is thoroughly purged with a dry inert gas (such as nitrogen) and evacuated before opening or refilling. If the quantity of fluorine to be purged is large, the purge system should include a fluorine-hydrocarbon-air burner, scrubber, and stack to prevent any undue exit hazards. A soda lime tower followed by a drier should be included in the vacuum line to pick up trace amounts of fluorine in order to protect the vacuum pump.

8. Wear face shields made of conventional materials, or preferably transparent highly fluorinated polymers like Genetron Plastic VK,* whenever approaching equipment containing fluorine under pressure. All face shields afford limited though valuable protection against air-diluted blasts of fluorine.

9. Inspect all areas containing fluorine under pressure for leaks at suitable intervals. Repair all leaks at once, but not while the system contains fluorine. Ammonia vapor expelled from a squeeze bottle (containing ammonium hydroxide) at suspected points may be used to detect leaks. Filter paper moistened with potassium iodide solution is a very sensitive means of detecting fluorine (down to about 25 ppm). Hold the potassium iodide paper with the aid of 18-24-in.-long metal tongs or forceps. The odor of fluorine is sufficiently strong so that it can be detected in very low concentrations. Fluorine will also fume readily in air.

10. Be sure of adequate ventilation. There should be a minimum of 10 air changes per hour for enclosed spaces. Portable, floor-level, 36-in. fans are desirable for auxiliary ventilation at outdoor installations or semi-open installations.

11. Strategically locate positive instant-acting types of safety showers and eye-washing fountains near the area where fluorine is being used. Test these at least weekly.

12. Locate air-line hose masks in strategic positions for use in emergencies.

13. Identify all equipment, pipe lines, etc. by distinctive colors and signs.

14. Be sure that personnel work in pairs and within sight and sound of each other, but not in the same immediate working area. Only trained and competent personnel should be permitted to handle fluorine. Frequent checks should be made of the operation.

15. Provide an alarm system so that the area may be alerted and cleared if needed.

In addition, observe the following general rules:

1. Never drop or strike cylinders with tools, or permit them to strike each other violently.

2. Assign cylinders a separate and definite area for storage. The area should be dry, cool, well ventilated, and preferably fire-resistant.

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*A product of Allied Chemical Corporation.

Protect cylinders from excessive temperature rise by storage away from radiators or other sources of heat. Storage conditions should comply with local and state regulations.

3. Leave the valve protection cap in place until after the cylinder has been secured against a wall or bench, or placed in a cylinder stand, and is ready to be used.

4. Avoid dragging, rolling, or sliding cylinders, even for a short distance. Move cylinders with a suitable hand truck.

5. When returning empty cylinders, close the valve before shipment, leaving some positive pressure in the cylinder. Replace any valve outlet and protective caps originally shipped with the cylinder. Mark or label the cylinder EMPTY. Do not store full and empty cylinders together.

6. Do not subject any part of a cylinder to a temperature higher than 125°F. Never permit a flame to come in contact with any part of a compressed-gas cylinder.

7. Before using fluorine, read all data sheets and supplier's information.

APPENDIX G

Physical Properties of Oxygen and Hydrogen[10]

	Oxygen	Hydrogen
Formula	O_2	H_2
Molecular weight	31.9988	2.0159
Density		
Gas, g/liter	1.429 (0°C)	0.0899
Liquid, g/cc	1.149 (-183°C)	0.070
Solid, g/cc	1.426 (-252.5°C)	
Melting point, °C	-218.4	-259.14
Boiling point, °C	-183.0	-252.5

APPENDIX H

Hydrogen Detector

(From Davis Hydrogen Detection System, Model No. 11-36XX-3, Operation-installation-maintenance Manual, Davis Emergency Equipment Co., Inc., Newark, New Jersey)

1. Introduction

The Davis Series 11-36XX Hydrogen Detection System is designed to continuously sense the atmosphere for hydrogen gas and continuously indicate the concentration in percent of the lower explosive limit (% L.E.L.). Should the hydrogen concentration exceed a predetermined limit, the instrument gives visual and audible alarms. A data sheet for the hydrogen detection system is shown on Table XIII.

TABLE XIII. Davis Hydrogen Detection System Data Sheet

DAVIS MODEL NO.	11-36XX-3	DAVIS SERIAL NO.	64-122
NO. OF ANALYZING HEADS:	THREE (3)	INDICATING	☒
		RECORDING	☐
		ALARM	☒
OPERATING CURRENT:	115 VOLTS AC, 60 CYCLES, 1 PHASE		
FILAMENT VOLTAGE:	0.75 VOLTS DC ACROSS REFERENCE FILAMENT		
UNIT CALIBRATED ON:	0-100% L.E.L. HYDROGEN IN AIR		
SCALE RANGE:	0-100		
NO. OF ALARM POINTS:	ONE (1)	SETTING(S):	ADJUSTABLE
SCALE READING ON DAVIS CHECK GAS (1% H_2 IN AIR):	25		
SAMPLE FLOW:	BY DIFFUSION		
REFERENCE DRAWINGS:	NO. 11-36BA-S-15, REV. A	- WIRING DIAGRAM	
	NO. -	- FLOW DIAGRAM	
	NO. 11-36BA-A-11, REV.,	- ASSEMBLY DIAGRAM	

2. Theory

The Series 11-36XX Hydrogen Detection System uses the principle of catalytic combustion for the detection of hydrogen. Catalytic combustion takes place on the surface of a catalyst when the catalyst is exposed to a mixture of air and a combustible gas. With the correct temperature, catalytic combustion unites the combustible gas with the oxygen in the air on its surface when the mixture is normally too lean to have any combustion. The reaction of the combustible gas on the catalyst raises the temperature of the catalyst in proportion to the percent of combustible gas present. The catalytic element used is a coil of platinum alloy wire.

When a sample containing hydrogen is passed over the wire, or filament, it burns on the surface of the filament, increasing its temperature and thus its electrical resistance, in proportion to the amount of hydrogen present.

The Davis Series 11-36XX systems use two filaments set up in two legs of a balanced Wheatstone Bridge circuit. One filament is catalytic, the other is noncatalytic. Both of these filaments are housed in the same chamber in the cell in order to compensate for ambient-temperature variations.

3. Electrical Circuitry

One reference (noncatalytic) and one active (catalytic) filament form two legs of a balanced Wheatstone Bridge circuit. Two fixed wire-wound resistors and a precision potentiometer constitute the remainder of the bridge circuit. The precision potentiometer permits bridge balancing or zero adjustment. This control is accessible from the front panel and is identified as ZERO ADJUST.

Bridge unbalance due to hydrogen gas burning on the surface of the filament provides the necessary output signal, which is indicated on a meter. The span of the instrument is controlled by a precision potentiometer connected in a voltage-divider circuit. This resistor is set so that a 10-mV dc signal will be transmitted to the meter on a 100% L.E.L. hydrogen concentration. The resistor, identified as % L.E.L. CALIB, is accessible on the inside of the instrument.

Bridge excitation voltage is furnished by a full-wave, bridge-type dc power supply. Excitation voltage is approximately 1.50 V dc at 1.0 A, and is controlled by the FILAMENT VOLTAGE ADJ. rheostat. This control is accessible from the inside of the instrument.

The alarm set point is determined by the position of the index pointer on the front of the meter and is adjustable over the entire scale.

When a gas concentration reaches the predetermined alarm set point, the movable meter pointer makes contact with the fixed pointer (index pointer). This allows the alarm relay to become energized, which, in turn, allows the red ALARM light to come on, and the green SAFE light to go out. The alarm circuit will not reset itself and must be reset manually. This is accomplished by momentarily throwing the switch to the RESET-ALARM OFF position. After the alarm circuit is reset, the switch should be returned to the NORMAL OPERATION position.

The amber ATTENTION light comes on when the switch is in the RESET-ALARM OFF position.

On either active or reference filament burnout, the blue FILAMENT light comes on. This light is actuated by the deenergizing of the FILAMENT relay.

A CIRCUIT TEST pushbutton is provided to check the alarm circuit. When the CIRCUIT TEST pushbutton is pressed, the bridge circuit is unbalanced and simulates an alarm condition.

4. Diffusion Sample System

The remote analyzing heads use diffusion and convection to obtain a sample of the air. No pumps or tubes are required.

Convection supplies the sample from the atmosphere to the head. The convection is due to gas densities, different than air. When the hydrogen leaks into the area being monitored, it will rise toward the ceiling, and through the analyzing head. A sintered-metal flame arrestor, which exposes the filaments to the outside, allows the hydrogen gas to diffuse into the cell where it is detected.

APPENDIX I

Construction Details for a Typical Glovebox[16]

This appendix describes a typical CENHAM* two-module glovebox (shown in Fig. 25). The main body of the glovebox is the frame, which is a weldment of a few basic component members. The members are formed from 1/8-in.-thick (11 gauge), cold-rolled sheet steel. The stringers or main outer frame members, 28 in. long, are formed with a 2-in. radius. The flat mullions, or inner frame members, 3 in. wide, are reinforced with P-1000 series Unistrut** channels, which add structural rigidity and provide a means of mounting laboratory equipment within the glovebox. The mullion corners match the radius of the stringers and provide the 4-in. minimum radius required for the weatherstrip seal. The end corners are formed on a 2-in. spherical radius and provide the weatherstrip radius. The members are assembled on a welding fixture and butt-welded together to form the frame. The frame is welded to a 1/2-in.-thick steel floor plate. The floor plate provides a firm base for equipment and adds rigidity to the structure.

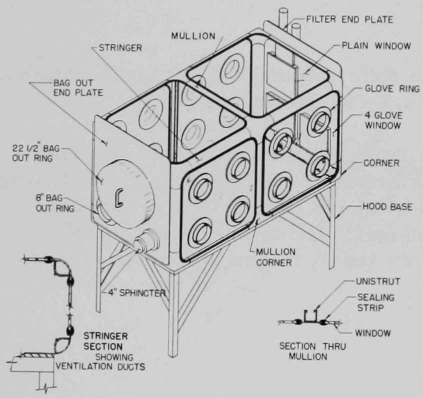

Fig. 25. CENHAM Two-module Glovebox. ANL Neg. No. 108-3599 Rev. 1.

The glovebox rests on a steel angle frame, which places the inside work surface of the box 36 in. off the floor and the center of the lower or working gloveports 48 in. from the floor.

The 3/16-in.-thick steel end panels are welded to the glovebox frame and are designed with apertures that allow access to the interior for services and equipment. One end panel contains the inlet and outlet filter housings and has a flanged connection for a glovebox-to-glovebox transfer lock (not applicable to the engineering-scale alpha facility). This transfer lock contains a tray on a compound roller slide, which allows easy transfer between two interconnected gloveboxes within the "reach" limits of the gloves. Both the filter-housing doors and the transfer-lock door have the same design.

The other end panel (at the bagout end) contains 22- and 8-in.-dia bagout ports. The 8-in. port has a plastic glove ring. The large port has

*ANL Chemical Engineering Hood, Alpha Module.
**Unistrut Corp., Wayne, Michigan.

a formed stainless steel sheet-metal ring. Each port, when not in use, is covered on both the inside and outside to prevent mechanical damage to the plastic bagout pouch and reduce moisture diffusion. These ports may be used to transfer materials into or out of the box. This end panel also contains a 4-in.-ID push-through entry port (sphincter assembly; see Fig. 18), which uses replaceable canisters, aluminum cans, and a seal-ring arrangement for transfer into the box only. Each canister is fitted with commercially available 4-in.-ID oil seal rings. A canister is sealed at its outside diameter by larger oil seal rings mounted on the port and can be transferred into the box by pushing in a replacement canister. This operation can be done without shutting down or cleaning up the glovebox. The useful life of the port is greatly prolonged because this method allows replacement of canisters when their internal seal rings become worn.

An inexpensive electrical feedthrough, used on the end panels, is simply a large brass bolt that has been drilled to take mineral-insulated cable. The mineral-insulated cable sheath is soldered into the bolt, and the entire feedthrough unit is sealed to the glovebox end panel using a commercially available Stat-O-Seal.* Pipe couplings welded into the end panels permit connection of fluid lines.

The internal ventilation ductwork allows for either a once-through or a recirculating gas system. The ducts are formed by radiused modular sections fitted to the curved stringer sections at both the top and bottom of the glovebox. The filter housings are designed to permit changing of filters from inside the glovebox. The ventilating gas is supplied at the bottom and removed from the top. Both the supply and exhaust gas streams may be filtered through high-efficiency, fire resistant filters.

Manufacturing specifications call for the entire welded glovebox assembly to be tested for weld soundness by the dye-penetrant method. All welds that tests indicate are questionable are repaired in an effort to reduce the probable leaks at final helium leak testing. After the surface is degreased and prepared for finishing, Amercoat No. 35** paint is applied on all carbon steel parts on both the inside and outside of the box, but not on the weatherstrip seal surface on the frame, which is masked off.

The ceiling and side panels of the glovebox are 3/8-in. safety glass, $35\frac{3}{8}$ in. square with corners rounded to a $3\frac{11}{16}$-in. radius with the same tolerances as used on the test panels. The glass panels are attached to the frame proper with Neoprene weatherstrip. The sealing compound, EC-801 B-8, is first applied by gun to the narrow 1/8-in. groove of the weatherstrip. The strip is fitted into the frame window opening. The glass panel is fitted into the weatherstrip after sealer is applied in the wide

*Parker Seal Co., Culver City, California.

**Amercoat Corp., Brea, California.

3/8-in. glass channel (see Fig. 26). The weatherstrip locking lip is closed to complete installation. The side panels have plastic glove rings mounted on 18-in. centers, allowing four glove rings per panel. The completely assembled and painted glovebox is approved after passing a leak test (with the leak rate not exceeding 0.05% of the total volume of air each hour).

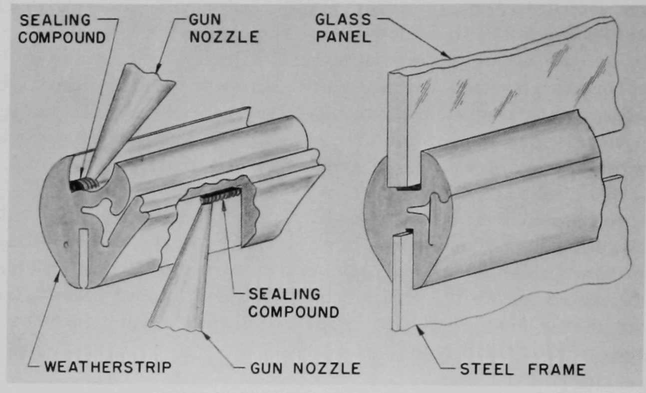

Fig. 26. Weatherstrip Seal Installation.
ANL Neg. No. 108-3602.

Glove-port covers, which protect the gloves from mechanical damage, are frequently used on the glove rings.

APPENDIX J

Material Transfer Bag Specifications

The material transfer bags used in the facility are fabricated of polyvinyl chloride plastic and conform to the following specifications:

1. Material

Vinyl film KDA-2076.* Thickness 0.020 in.

2. Seals

All seams and seals are to be made by dielectric heat sealing; minimum width of seal to be 1/4 in.

Bags are to be gas-tight. All seals must be capable of withstanding a pull corresponding to 60% of the strength of the material.

Longitudinal seams are to be made by overlap seal. Seamless tubing may be used if proper size and material are available.

The bottom of the bag is formed by pressing together the bottom edges and making a seal having a minimum width of 1/4 in.

The open end of the bag is to be folded back 2 in. and sealed so that the distance from the bag lip to the front edge of the seal is 1/4 in.

3. Packaging

The vinyl film must not cling to itself.

Precautions should be taken in packaging to avoid sharp creases which could be formed when the bags are folded for shipment.

*A product of Union Carbide Corp., New York City, N.Y.

APPENDIX K

Radiation Instrumentation

Radiation units are defined in Table X, maximum permissible exposures for external radiation are listed in Table XI, and maximum permissible neutron-flux densities in Table XII (all in Appendix C).

1. Personal Radiation Monitors

a. Pocket Dosimeters

Type:	Quartz fiber electroscope.
Dimensions:	Collection volume of ~2 cm^2.
Response reading:	Self-reading by visual inspection of scale.
Radiation detected:	Gamma and neutrons (in roentgen quantities, cumulative).
Radiation ranges:	Various (100 and 200 mR; 1, 5, 10, and 50 R).

b. Film Badges

Type:	Various.
Dimensions:	Approximately $1\frac{1}{2}$ by 2 by 1/8 in. thick (film packet).
Response reading:	By service personnel, with optical equipment.
Radiation detected:	X-ray gamma, or neutrons (depending on film emulsion).
Radiation ranges:	Various (depending on film type).

2. Hand and Foot Alpha Monitors

Counter type:	Gas proportional alpha counter.
Probe type:	Flat plate, aluminized Mylar* window, gas-purged.
Probe dimensions:	5 by $10\frac{1}{2}$ in. with window area of ~340 cm^2.
Counter gas:	P-10 (90% argon, 10% methane).

*A product of E. I. duPont de Nemours and Co., Wilmington, Delaware.

Meter:	Zero to 1000 counts/min with range switch (X0.3, X1, X10, X30, X100).
Audio monitoring:	Loudspeaker (variable volume control).
Power requirements:	External 110 V ac.

3. Constant Air Monitor (see Fig. 27)

Counter type:	Alpha and beta-gamma gas proportional counters.
Probe type:	Flat plate, aluminized Mylar window, gas-purged.
Counter gas:	P-10 (90% argon, 10% methane).
Meter:	0 to 1.0 or 0 to 3 with range switch (10^2, 3×10^2, 10^3, 3×10^3, 10^4, 3×10^4, and 10^5), one each for beta-gamma and alpha output; ratio meter with difference sensitivity switch (5% α to 0 to 5% β-γ, 10% α to 0 to 10% β-γ, 25% α to 0 to 25% β-γ, 50% α to 0 to 50% β-γ).
Audio monitoring:	Alarm when alpha ratio reaches preset limit; alarm when beta-gamma ratio reaches preset limit.
Power requirements:	External 110 V, ac.

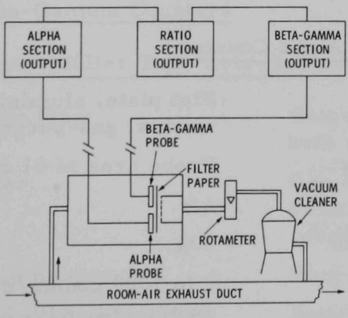

Fig. 27

CAM-5 System

4. Stack Air Monitor (see Fig. 28)

Counter type:	Scintillation-type alpha counter.
Probe type:	Flat plate, aluminized Mylar window, ZnS-coated Lucite light pipe with built-in photomultiplier tube.
Readout range:	1 to 1000 counts/sec.
Audio monitoring:	Alarm when count rate reaches preset limit, alarm (electronics trouble) when count rate goes below a preset limit.
Power requirements:	External 110 V ac.

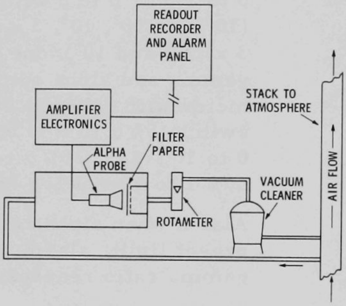

Fig. 28

Stack Air Monitor System

5. Portable Alpha Counters

a. Air Proportional Alpha Counter

Probe type:	Flat plate, aluminized Mylar window, gas-purged.
Probe dimensions:	Probe area of 61 cm^2.
Counter gas:	Air.
Geometry of yield:	50%.
Meter:	0 to 1000 counts/min with range switch (X1, X10, X100).
Audio monitoring:	Plug-in jack for earphones.
Power requirements:	Battery-operated.

b. Gas Proportional Alpha Counter

Probe type:	Flat plate, aluminized Mylar window, gas-purged.
Probe dimensions:	Probe area of 61 cm^2.
Counter gas:	Propane.
Meter:	0 to 1000 counts/min with range switch (X1, X10, X100).
Mode control:	Probe high-voltage switch, alpha or beta.
Audio monitoring:	Plug-in jack for earphones.
Power requirements:	Battery-operated.

c. Scintillation-type Alpha Counter

Probe type:	Flat plate, aluminized Mylar window, ZnS-coated Lucite light pipe with built-in photomultiplier tube.
Probe dimensions:	Probe area of 61 cm^2.
Meter:	0 to 2000 counts/min with range switch (X1, X10, X100).
Audio monitoring:	Plug-in jack for earphones.
Power requirements:	Battery-operated.

6. Portable Beta-Gamma Counters

a. Geiger-Müller Tube Beta-Gamma Survey Meter

Probe type:	Geiger-Müller tube with sliding beta shield.
Meter:	0 to 20 mR/hr with scale-range switch (20, 2.0, and 0.2 mR/hr ranges).
Audio monitoring:	Plug-in jack for earphones.
Power requirements:	Battery-operated.

b. Juno Photon-exposure-rate Survey Meter

Probe type:	Ion chamber with sliding filters for alpha and beta rejection.

Meter:	0 to 50 mR/hr with scale-range switch (X1, X10, X100).
Power requirements:	Battery-operated.

7. Portable Neutron Counter

Counter type:	Gas proportional neutron counter.
Probe type:	Gas proportional chamber filled with boron trifluoride.
Probe dimensions:	Approximately 2.7 in. long by 0.94-in. diameter.
Probe shielding:	Cadmium, 1/32 in. thick.
Fast-neutron moderator:	Equivalent of $1\frac{1}{4}$-in. paraffin around the detector housing.
Meter:	0 to 500 events/min with range switch (X1, X10, X100, X1000).
Audio monitoring:	Plug-in jack for earphones.
Power requirements:	Battery-operated.

APPENDIX L

Criticality Detector

The Argonne-developed criticality-alarm system (RAM-A, RAM-B, and RAM-C) is a specialized remote-area radiation monitor for the primary purpose of detecting criticality accidents and providing audible alarms for personnel in the vicinity. Its secondary purpose is to provide centralized indications of the remote radiation levels. Both purposes are accomplished with good reliability, stability, and serviceability.

Each system has one or more detectors in the area where the radiation level is to be monitored and includes one or more alarm horns installed in the area. Equipment at a central location in a given building or area provides all control functions, indications, and power for that system. Collectively, such equipment forms the control console of the system.

The RAM-A, RAM-B, and RAM-C versions of the system differ mainly in the maximum number of detectors and alarm horns that they can accommodate. The RAM-A can accept up to 10 detectors and six alarm horns, the RAM-B up to four detectors and six alarm horns; the RAM-C has only one detector and either one or two alarm horns.

1. Detector Unit

The detector unit consists of an ion chamber and logarithmic amplifier in a common housing. The ion chambers are of two types: (1) gamma sensitive or (2) primarily sensitive to neutrons and having reduced gamma sensitivity. The neutron sensitivity of the latter is enhanced by the use of a combination shield and moderator of lead and paraffin. The radiation level is converted to an electrical signal in the detector unit and transmitted, up to several hundred feet, to a station unit at the central location. (The detector unit in the alpha facility is the gamma-sensitive type. It is set to actuate the alarm at a radiation level of 20 mR/hr.)

2. Station Units

All station units of a system are located at the control console. Each station unit, together with its associated detector, comprises one channel of that system. The station unit consists of high- and low-level trip circuits and a small radiation-level meter. When a high-level trip circuit is actuated in any station unit, all the alarm horns of the system sound, and a remote alarm signal is sent to the Criticality Alarm Panel at the Building 200 ANL Communications Center. When a low-level trip circuit is actuated, it causes a buzzer to sound, indicating a loss of the minimum signal (supplied by a small radioactive "bias" source mounted on its ion chamber) and, therefore, some electronic difficulty in that channel.

3. Control Unit

The control unit controls the main alarm circuit (i.e., the horns and remote alarm circuit) and is capable of disabling the entire circuit or selected channels, when necessary. From the control unit, an internal radioactive check source can be exposed in the remote detector of any one selected channel to ascertain the channel's response to radiation--all without causing an alarm. A large meter on the unit can be used to measure the internal power-supply voltages as well as the radiation level from a selected channel.

4. Horn and Buzzer Unit

The horn and buzzer unit contains the horn timing circuits; it simultaneously provides power for all of the horns in a 1/2-sec "on" 1/2-sec "off" cycle. This unit also contains the buzzer that will sound with a low-level trip signal from any station unit or as a result of any malfunction that causes the battery current to deviate from the narrow range near zero. The buzzer also will sound whenever the main alarm circuit is actuated, whether the main alarm circuit is disabled or not. The buzzer may be silenced without correcting the source of the trouble. If another trouble should develop from any source before the first is corrected, it will sound again. If required, the buzzer may be located at a remote place where it commands better attention.

5. Power Unit

The power unit provides all necessary operating voltages from two power supplies, which, in turn, operate from ac line power. These two power supplies provide (nominal) +25-V and -10-V power, which also keeps the two sets of storage batteries on a floating charge.

With the loss of ac line power, the storage batteries provide normal operation of the system for 4 hr. If the buzzer is promptly silenced, the period of operation on batteries alone may be as long as 16 hr. The +25-V battery also supplies the extra current needed when the alarm horns sound.

Each horn is an electrically operated vibratory unit with a resonating trumpet section that enhances the fundamental frequency of the tone produced. All the horns on a system operate simultaneously. This type of horn and the pulsed "on-off" operation provide both an attention-commanding sound and maximum contrast with most interfering noises.

APPENDIX M

Fire Extinguishers for Facility Use

Three types of portable fire extinguishers are available for use in the facility: carbon dioxide fog (CO-TWO), water (pump-type), and pressurized dry powder (sodium bicarbonate). All extinguisher units are outside the gloveboxes, and only the dry-powder type is adapted for use in fighting fires within the gloveboxes.

All extinguishers are located permanently, and care must be taken to keep the areas around them clear. The ANL Fire Department is responsible for maintaining all extinguishers.

1. Carbon Dioxide Fog

Uses:	Oil, paint, flammable liquid, and electrical fires.
Number available:	Two.
Locations:	Work area and control-panel area.

2. Water

Uses:	Paper, wood, and rag fires.
Number available:	One.
Location:	Building corridor, outside isolation room.

3. Pressurized Dry Powder

Uses:	Universal; modification (see Fig. 29) has restricted application to glovebox fires.
Number available:	Three.
Locations:	Process cell, work area, and isolation room.

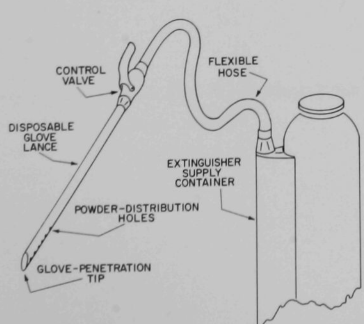

Fig. 29

Modified Fire Extinguisher for Use through Glovebox Gloves

APPENDIX N

Emergency Electric Power System

The emergency power for the facility comes from the building emergency generator. The normal electrical power is fed into the facility by two separate lines from a substation (designated B). All equipment that requires emergency power is connected to one of these lines (principal lines). Equipment connected to the other line has no emergency backup power available.

The principal line is interlocked with the emergency generator (diesel-driven) located in the basement of the building. When normal power fails, the generator starts automatically and, after an 8-sec delay, begins supplying power to the principal line.

The following facility equipment is connected to the principal line:

Process scrubber pump

Ventilation booster blower

Ventilation scrubber pump

Ventilation fans No. 2, 3, and 4. (No. 4 normally running, No. 2 and 3 on standby)

Stack air monitor.

Loss of normal power will result in complete darkening of the building. Emergency lights (battery-operated) are provided that automatically turn on when normal power is lost. Emergency lights are located in the process cell, the work area, and all main corridors of the building.

APPENDIX O

Emergency Air Supply System (see Fig. 30)

Loss of building air flow to the facility would, in the absence of safeguards, have the following consequences:

1. Process-gas supply valves (normally closed type) would close.

2. Ventilation dampers (butterfly valves in the ductwork) would open.

These occurrences would result in shutdown of any run in progress and a minor imbalance of the ventilation pattern.

Two backup systems have been provided to avoid difficulties anticipated in the event that flow of building air is interrupted:

1. A standby compressed-air cylinder manifold to maintain the pressure at the process-gas supply valves (instrument air),

2. An air compressor and tank to maintain pressure at the ventilation damper motors.

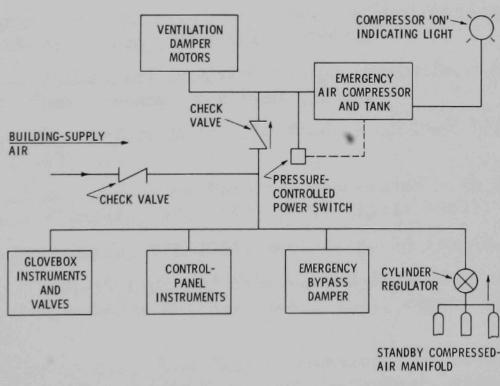

Fig. 30. Emergency Air Supply System

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